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TECHNICAL REPORT NO. 3-726

# MOBILITY ENVIRONMENTAL RESEARCH STUDY A QUANTITATIVE METHOD FOR DESCRIBING TERRAIN FOR GROUND MOBILITY

Volume VI

## SELECTED AIR-PHOTO PATTERNS OF TERRAIN FEATURES

by

R. E. Frost, P. L. Johnson, R. D. Leighty
V. H. Anderson, A. O. Poulin and J. N. Rinker

May 1966

Sponsored by

Advanced Research Projects Agency
Directorate of Remote Area Conflict

Service Agency

U. S. Army Materiel Command

Conducted for

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

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ARMY-MRC VICKSBURG, MISS.

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## FOREWORD

This study constitutes a portion of the Mobility Environmental Research Study (MERS), sponsored by the Office, Secretary of Defense, Advanced Research Projects Agency (ARPA), Directorate of Remote Area Conflict, for which the U. S. Army Engineer Waterways Experiment Station (WES) is the prime contractor, and the U. S. Army Materiel Command (AMC) is the service agent. The broad mission of Project MERS is to determine the effects of the various features of the physical environment on the performance of cross-country ground contact vehicles and to provide therefrom data which can be used to improve both the design and employment of such vehicles. A condition of the project is that the data be interpretable in terms of vehicle requirements for Southeast Asia. The funds employed for this study were allocated to WES through AMC under ARPA Order No. 400.

This volume of the report is concerned with the application of existing air-photo techniques in describing terrain conditions pertinent to ground mobility, and it presents a catalog of terrain features that affect ground vehicle performance and are identifiable as air-photo patterns. This study was performed by the U. S. Army Cold Regions Research and Engineering Laboratory (CRREL), U. S. Army Materiel Command.

This volume and the field effort which contributed to its preparation represent the combined efforts of the following CRREL investigators and personnel: Robert E. Frost, civil engineer (CRREL representative in charge of the project and responsible for surface geometry); Philip L. Johnson, ecologist (vegetation); Robert D. Leighty, civil engineer (surface composition); Vernon H. Anderson, geologist (hydrologic geometry); Ambrose O. Poulin, civil engineer (surface geometry); and Jack N. Rinker, physical scientist (comparative photography). Special acknowledgement is extended to Roger B. Arend, Pvt. Lawrence A. Colyer, and Pvt. Gary Cunningham for

their assistance in the field and in the laboratory; to Stephen B. McLaughlin for scientific illustrations; to Thomas L. Marlar, David M. Atwood, and John G. McConnel for photographic reproduction; and to Miss Brenda Peterson and Mrs. Marilyn Valley for typing. The assistance of the MERS Field Detachment under command of Lt. Col. Arthur R. Simpson and the field assistance of Messrs. Thomnoon, Anuvat, and Taweesak, civil engineers, are acknowledged with thanks. The assistance of WES personnel in the field and the use of portions of their field data are also acknowledged with thanks. Permission granted by the American Geographical Society to reproduce the four soil maps of Thailand, showing soil types and distribution as mapped by Pendleton, is gratefully acknowledged.

Directors of CRREL during the conduct of this study and preparation of this report were Col. W. L. Nungesser, CE, and Col. P. G. Krueger, CE. Technical Director was Mr. W. K. Boyd.

Directors of WES during the conduct of this study and preparation of this report were Col. Alex G. Sutton, Jr., CE, and Col. John R. Oswalt, Jr., CE. Technical Director was Mr. J. B. Tiffany.

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CONTENTS

## SUMMARY

This volume contains a catalog of photographs of Thailand terrain features described in such a way that the information can be used in making estimations of their effects on the performance of ground vehicles. Results of a limited study to determine the effects of film emulsion and photo scale on the acquisition of terrain information from aerial photographs are also presented.

## MOBILITY ENVIRONMENTAL RESEARCH STUDY: A QUANTITATIVE METHOD FOR DESCRIBING TERRAIN FOR GROUND MOBILITY

### VOLUME VI: SELECTED AIR-PHOTO PATTERNS OF TERRAIN FEATURES

### PART I: INTRODUCTION

1. Aerial photographs (air photos) are an important source of terrain information pertaining to geology, soils, vegetation, hydrology, and surface configurations; as such, they have been useful to the scientific, engineering, and military professions. It is reasonable, therefore, to assume that air photos can be used to provide terrain information for ground mobility purposes. In addition, interpretation of air photos offers a practical means of extending ground control data to large areas, thus enhancing the construction of maps.

#### General Background

2. Recognizing the utility of air photo interpretation techniques for obtaining terrain information, the U. S. Army Engineer Waterways Experiment Station (WES) as part of its Mobility Environmental Research Study (Project MERS) included in its program plan tasks for exploiting air-photo techniques and acquiring new photographic coverage of selected areas in Thailand. The new photographs were to include large- and medium-scale air photos made using three film emulsions to study the effects of photographic scale and film emulsion in delineating terrain characteristics.

3. Because of the experience and special capabilities in research and application of air-photo interpretation techniques of the Photographic Interpretation Research Division of the U. S. Army Cold Regions Research and Engineering Laboratory (CRREL), WES solicited the assistance of CRREL in developing plans and assuming responsibility for pursuing agreed-upon work plans for the tasks concerned with air-photo work.

4. A work plan developed by CRREL and WES was approved in March 1964.

CRREL was to participate for a one-year period in a three-phase study in aerial sensing to obtain detailed information about terrain conditions in seven areas (approximately 7556 square miles) in Thailand (see fig. 1) so as to facilitate the design and operational aspects of a planned vehicle test program. Phase 1 included a preliminary analysis of existing literature, maps, data, and air photos from which a draft report was to be prepared to consist of a set of first-order terrain factor maps (scale 1:50,000) showing the type and distribution of soils, vegetation, landforms, and hydrologic features, and a text presenting a description of the terrain factors which were mapped and the methods used to interpret them from the photographs. The terrain factor families, terrain factors, and class ranges desired for ground mobility purposes are given in table 1. Phase 2 consisted of a field study to verify maps and obtain, through contract, new (1:5,000 and 1:15,000) air photos of each area. Phase 3 included a laboratory reevaluation and correction of maps and preparation of a final report. The final report was also to include a study of the effects of photo scale and film emulsion on the acquisition of terrain information.

5. Phase 1 was completed in August 1964 after the areas to be mapped were reduced to 4211 square miles. Following the completion of phase 1, the CRREL work plans were modified by WES at the request of the project sponsor, Advanced Research Projects Agency (ARPA), to reduce the overall MERS program to achieve more restrictive objectives. As a result, Hat Yai was eliminated as a study area and phase 2 was changed so that the CRREL field party could devote more effort to obtaining detailed field measurements and observations for two study areas (Lop Buri and Chanthaburi). This phase was conducted during September and October 1964 at which time the contract to obtain new air-photo coverage of the original seven study areas was extended. The objective of phase 3 was also changed from factor mapping to the preparation of a ground mobility-oriented catalog of air-photo patterns of Thailand terrain.

## Purpose and Scope

6. The primary purpose of this study is to compile a catalog of photographs of Thailand terrain features and describe them in such a manner

that the information can be used in making estimations of their effects on the performance of ground vehicles. A secondary purpose of this study is to determine the effects of photo scale and film emulsions on the acquisition of terrain information.

7. The terrain-factor families considered are: surface composition, surface geometry, vegetation, and hydrologic geometry. Examples of terrain features are included for each factor family, and where a relation exists between a terrain feature and several terrain-factor families, the relation is identified. Terrain information obtained from available air photos, maps, literature, and field data collected at selected locations within the study areas were used in describing terrain features included in this report. Most of the features are from the Lop Buri and Chanthaburi study areas where the CRREL field parties did most of their work. The procedures established by WES for collecting field data were generally followed; however, in a few instances they were modified to expedite field sampling. The laboratory and field work were accomplished using existing photographs. The acquisition of new photographs was delayed considerably by long periods of adverse weather. New large- and medium-scale photographs obtained during the dry season were available for the Lop Buri area prior to the completion of this report; however, the delay in acquisition of new photographs allowed only partial fulfillment of the objectives of the study on comparative photography (scale and film emulsion).

8. The compilation of a complete catalog of Thailand terrain features is not within the scope of this study. Therefore, to allow for the future addition of various items, the catalog was prepared in an open-end form. Most of the examples of air photos included in the report were taken from 12-year-old available photographs at a scale smaller than 1:20,000. Most of the photographs available were at a scale of 1:40,000. The quality of the photographs varied considerably. New and larger scale photographs of the selected patterns, along with other patterns and field data, can be added to the catalog as they become available.

## The Catalog

9. After study of the terrain factors and class limits indicated in

table 1, it will be evident that considerable deviation was necessary from the idea of obtaining this information from photo interpretation alone. Instead, attempts have been made to correlate these factors, to one degree or another, with the appearance in air photos of their associated terrain elements and their influence on the air-photo pattern. The purpose of this approach is to provide a method whereby the general character of the terrain factors can be deduced from their air-photo patterns. Detailed information for many of the factors would then have to be obtained by other means. No other approach is possible through the exclusive use of medium- and small-scale photography.

10. The following portions of the catalog consist of five parts, four of which are concerned with terrain features associated with the four factor families, and one with certain aspects of comparative photography. The terrain features associated with the factor families are arranged in the following order: surface composition, surface geometry, vegetation, and hydrologic geometry. The text presents a discussion of five aspects of photo analysis. These are: recognition on air photos, appearance on the ground, dimensions, relation to other factors, and regional distribution. Each of these five aspects is then considered with reference to the photo pattern of specific features pertinent to the factor family in question. The illustrations, which follow the text, consist of aerial mosaics, stereopairs of air and ground photos, air photos, ground photos, and sketches.

11. The catalog's limitations, resulting from the use of inadequate photography, are significant and consequently it should not be considered representative of the state of the art. However, since it is the only known compilation of aerial photographic patterns of Thailand supplemented with ground data on Thailand, it should prove useful in obtaining information about Thailand terrain for ground mobility purposes. It may also have application to similar terrain in other Southeast Asian areas.

## State of the Art

12. Air photos cannot be used to obtain all of the terrain factor

data indicated in table 1, but conventional photo-interpretation procedures are useful in obtaining a qualitative understanding of the terrain, and this is a prerequisite to successful quantitative analysis of ground mobility. It should also be realized that making measurements from photographs is a highly refined technique and that it can be used at various levels of refinement. Although it may not be practical to map extensive areas at the very large scales that would be required for the degree of accuracy indicated in table 1, photogrammetric methods would be quite useful for mapping representative small areas.

13. The state of the art of photo interpretation will advance through continued research. Also, future terrain analysis by remote means will apply other aerial sensors, such as infrared, microwave, and radar scanners, doppler radar, and laser profilers, but additional research in the application of these sensors is needed before they can be applied to detailed terrain analysis.

## Photo-Interpretation Problems in Thailand

14. The majority of Thailand is either devoted to agriculture or covered with dense forests. The natural forests are found in all mountainous areas, as well as other areas not presently cultivated, and they present no unique problems to the photo interpreter beyond those concerned with obscuration of the underlying terrain.

15. The photo-interpretation problems involving agricultural areas are concerned with three orders of time change. First are the patterns reflecting cultural modifications by an agrarian economy over many years. Man's impact on the extensive lowland areas suited to rice cultivation involves local modification of the landscape and conservation of surface water. As a result, natural erosion features of the terrain that are often indicative of surface composition are obliterated by the continuing efforts of the farmers. The second order of temporal change is the product of an agrarian technological explosion in Thailand since World War II. During this period the government has devoted increasing efforts to the construction of major irrigation systems in the larger lowland areas and to

the introduction of new crops, such as corn. Also, large segments of the population are being resettled in new agricultural lands cleared from forests. The third and most transient of the time-dependent terrain changes results from the monsoon climate. The alternation of the wet and dry seasons is most crucial on flat valley floors, which may be flooded in November and baked dry in January. Vegetation varies in color and stage of growth, soil patterns are different, hydrologic features appear and disappear--all in response to the time of year.

16. Another factor limiting photo analysis in Thailand is the availability of suitable photography. Most of the existing photographs are over 10 years old, of small scale, and of variable quality, and the acquisition of new photographs is hindered considerably by cloud cover, haze, and, after the rice harvest, smoke.

## Reliability

17. Included in the presentation of most of the features of this catalog are statements of reliability for one or more aspects of the features. In many cases, the reliability estimates are qualitative rather than quantitative. In the case of the vegetation and hydrologic geometry factor families, the stated reliabilities are intended to apply generally for anyone with a working knowledge of air-photo interpretation. For surface composition and surface geometry, the stated reliabilities, though sometimes generally applicable, are intended to apply primarily to the authors of those sections of the report. This inconsistency results from the difference in complexity between the factor families.

18. Since a number of the terrain factors are of a dimensional nature, it is fitting that a statement be made regarding the usual conditions affecting the reliability of photographic measurements. These conditions are nominal photo scale, accuracy to which the scale at the given point can be determined (this requires knowledge of focal length, aircraft altitude, and elevation of measured points), dimensional stability of the photo, and precision of measurement on the photo. In general, in order to approach 100 percent reliability in making a horizontal measurement

with an accuracy of 1 ft from ordinary photos of good quality in an area of known nominal height above sea level and with relief on the order of 5 percent of the aircraft height above the terrain, a photo with a scale of about 1:1,000 or larger should be used. Reliability then varies in proportion to the scale of the photography. Using photography of the same scale for measuring heights photogrammetrically may result in 1-ft accuracy something on the order of 90 percent of the time. In lieu of photogrammetric measurement, heights can only be roughly estimated on the basis of previous experience, and the reliability would be strictly dependent on the experience and ability of the estimator.

## PART II: SURFACE COMPOSITION

19. Surface composition is concerned with the composition and physical properties of the materials composing the surfaces of the earth. Although surface composition includes both rock and unconsolidated materials, this part of the report considers primarily soils since the strength of the soil affects the operation of ground vehicles in performing cross-country missions. The soil strength must be great enough to support the vehicle and to provide traction so that the vehicle can accelerate or negotiate obstacles. Soil strength is affected by the kind of soil material and its moisture content; hence, soil strength changes with time depending upon daily weather conditions. The primary measure of soil strength is rating cone index (RCI); however, sheargraph measurements are also used to indicate the strength of the surface soil layer. The principal sources of published information used in this portion of the report are listed as references 1-7 in Literature Cited which follows the text of this report.

### Selection of Examples

20. Association of physical features, depositional processes, and land use lend themselves to identification from air photos; therefore, these characteristics are used in identifying soil groups. The air-photo patterns selected for inclusion in this catalog represent some of the major soil groups found in Thailand. Nine examples were selected and are listed below; six are considered major soil bodies as identified by Pendleton,[4*] who classified 21 groups of soils in Thailand and mapped them at small scale as shown in figs. 2-5. Laterite has not been recognized as a separate soil body since its occurrences, though numerous, are too small to map except at a very large scale. The remaining three examples are minor soil bodies selected primarily on the basis of landform.

* Raised numbers refer to similarly numbered items in Literature Cited.

| Major Soil Groups (Pendleton) | Minor Soil Groups |
|---|---|
| Bangkok clay | Natural levee |
| Ongkharak clay | Beach ridge |
| Tachin clay | Abandoned channel |
| Lop Buri clay | |
| Chiang Mai loam | |
| Chanthaburi clay | |

## Data Collected

21. The soils data are presented in table 2 for each of the selected soil groups. This table includes original field site numbers, location, sample depth, organic content, grain size, Atterberg limits, U. S. Department of Agriculture (USDA) and Unified Soil Classification System (USCS) soil types, specific gravity, moisture content, cone index, remolding index, rating cone index, and sheargraph values. These data were gathered by four field parties, each sampling with a slightly different objective; hence, none of the four collected all of the data at each site.

## Description of Catalog Examples

### Bangkok clay

22. One of the most extensive deposits of clay soils in Thailand is the Bangkok clay of the Bangkok Plain. Smaller deposits of this soil are found at other locations in Thailand.[4]

23. Recognition on air photos.

a. Appearance. There are three air-photo pattern indicators for Bangkok clay soils. These are: (1) the overall level surface, (2) microrelief differences confined to the vicinity of frequently occurring surface drainage channels, and (3) small sinkhole ponds. The sinkholes and drainage channels are usually identified by dark-toned grasses and brush which line their centers as shown in figs. 6, 7, and 8.

b. Contributing elements. The major contributors to recognition are: (1) proximity to major rivers and the ocean, (2) frequent abandoned channels, (3) nonterraced rice paddies adjusted in shape and orientation to the microrelief, and (4) home sites and tree vegetation restricted

to local high ground, usually on natural levees or adjacent to canals and streams.

c. Genetic description. This soil was derived from deltaic alluvium deposited in a saltwater environment.

d. Factor estimate reliability. Reliability of identification of this soil is estimated at 75 percent. Difficulties in recognition are encountered at gradational transition zones with other soils bordering the Bangkok Plain and in the vicinity of larger streams where natural levee soils have obscured the above-listed recognition elements.

24. Appearance on ground. The Bangkok Plain is extremely flat and only a few feet above sea level (fig. 8). Therefore, the subsurface soils are at or near saturation throughout the year in most locations. In the wet season the plain is flooded, while in the dry season the surface is characteristically dry with deep shrinkage cracks.

25. The Bangkok clay has a developed profile about 6 ft deep. Surface soils are usually dark-colored clays of high plasticity. Beneath this surface layer is a gray-colored clay of high plasticity having frequent variegated streaks and splotches of yellow, red, and brown.

26. Dimensions. Soil data for three sample sites in the Bangkok Plain about 9 miles southeast of Ayutthaya are given in table 2. These sites are indicated on the air photos (figs. 6 and 7).

27. Relation to other factors. High road and rail embankments will be found in areas subject to deep flooding.

28. Regional distribution. See Pendleton's soil map of Thailand (figs. 2, 3, and 4).

Ongkharak clay

29. Ongkharak clay is found in association with Bangkok clay but is of lesser areal extent. This clay has air-photo patterns different from the Bangkok clay, but the two clays have similar origins.

30. Recognition on air photos.

a. Appearance. This soil is characterized by very dark gray to black photo tones in the uncultivated areas in contrast with the light tones in the rice fields. In the dark areas, microrelief causes slight tone variations; low depressions are darker and local highs are relatively lighter. Uncultivated areas are usually found at locations farther removed from surface water sources. Rice cultivation

predominates adjacent to streams and canals and is recognized by the uniform, light tones. Examples of air-photo patterns are shown in figs. 9-11.

b. Contributing elements. These clays are found adjacent to the Bangkok clays. The surface soil layer is commonly black with dark organic matter. Alum (aluminum sulfate) accumulates on the surface soil in the dry season. Present are all the indicators mentioned for Bangkok clays but they are more subdued.

c. Genetic description. These soils were derived from deltaic alluvium deposited in a saltwater environment.

d. Factor estimate reliability. From the 1953 aerial photography (figs. 9 and 10) proper identification of this soil is estimated at 50 percent. Where natural black patterns exist, 100 percent identification of this soil is possible, but the uniform tones associated with rice cultivation make correct boundary delineation impossible. Comparison of 1964 aerial photographs (fig. 11) with the 1953 photography of the same area illustrates obliteration of natural soil patterns by rice cultivation practices. This reduces the probability of correct identification even further in cultivated areas.

31. Appearance on ground. The landform associated with the Ongkharak clay soils is a plain, but the soil is relatively infertile compared to Bangkok clays because of its very high acidity; thus the surface has not been modified as extensively by agricultural practices. Ground photographs (figs. 12 and 13) show the topography in the vicinity of soil sample sites 31 and 33. Profile development is not as deep as for the Bangkok clays and the surface soils are darker.

32. Dimensions. Field data in table 2 were obtained on 15-16 September 1964 at the sample sites indicated in figs. 9-11 and represent samples from uncultivated areas in high position.

33. Relation to other factors. None

34. Regional distribution. See Pendleton's soil map of Thailand (figs. 2 and 4).

Tachin clay

35. Tachin clay represents saline coastal mud flat and swamp-deposited alluvial soils. Only coastal saline clays are discussed below.

36. Recognition on air photos.

a. Appearance. The mud flat clays are associated with level

terrain located near a coast line or tidal stream and bordered by nipa palm or mangrove trees. Examples of air-photo patterns of mud flats are shown in figs. 14-16. In these illustrations, reclaimed land in rice cultivation has uniform, light photo tones, reclaimed land not planted in rice has dark photo tones, and nipa and mangrove tidal areas have much darker tones.

b. Contributing elements. See a above.

c. Genetic description. These soils are derived from Recent coastal mud flat or tidal marsh alluvium.

d. Factor estimate reliability. For soils with the above listed indicators evident on the aerial photographs, there is almost a 100 percent reliability for correct identification. Difficulties often occur and possibilities for errors in judgement may be experienced in situations where the cultural practices result in different photo tones and possibly texture.

37. Appearance on ground. Where mud flat areas are within tidal range, nipa palm and mangrove trees will be found, but above the tidal range, surface soils are usually cultivated in rice. Cultivated areas can be extended by removal of vegetation and construction of low dikes to prevent sea water flooding. Soils within nipa palm or mangrove areas, or in areas which have recently been cleared, will have high percentages of fibrous peat and other organic materials, whereas those areas reclaimed in the distant past will have little organic material. The surface soils are soft and light to dark brown in color depending upon such items as the moisture content, whether or not the surface is flooded, and accumulations of salt at the surface. The subsurface color below about 3 in. is slate gray. Representative ground photos in the area of sample sites are shown in figs. 17-20.

38. Dimensions. Data for the seven sample sites in mud flat soils south of Chanthaburi (shown in fig. 14) are presented in table 2. The data show a number of different soil types for these sample sites. The soils within nipa palm areas which lie within the range of tidal variation (sites 126 and 187) show high moisture and organic contents. Sites 127 and 143, representing soil areas which have been reclaimed recently and do not now lie within the tidal range, have medium to high moisture contents and high clay (site 127) or organic matter (site 143) contents. Sites 124, 144, and

145, representing higher areas which were reclaimed in the distant past, have less plastic soils and low moisture and organic contents near the surface.

39. Relation to other factors. Nipa palm and mangrove trees indicate the presence of the saline clays.

40. Regional distribution. See Pendleton's soil map of Thailand (figs. 2-5).

Lop Buri clay

41. The Lop Buri clay is derived from limestone parent materials and has three forms of landscape expression. Two forms are associated with karst topography: residual clay ridges and colluvial clay sinkholes or depressions. The third form, consisting of clay found on the slopes draining from the karst areas, is the alluvial apron (colluvium and alluvium).

42. Recognition on air photos.

a. Appearance. Fig. 21 is an air-photo mosaic of a karst area located about 15 miles southeast of Lop Buri. A stereopair of a portion of this mosaic is shown in fig. 22. Twelve years later, and at a larger photo scale, this area appeared as shown in fig. 23. The karst patterns are characterized by (1) generally level ridges of relatively uniform height but random width and orientation, (2) flat-bottomed depressions or sinkholes of variable areal extent which may or may not have connecting channels, (3) trees, dry crops and brush occurring only on the ridges, and rice cultivation found only in the sinkholes, and (4) uniform photo tones on the ridges and diverse tones in the sinkholes.

The alluvial apron patterns surrounding most of the karst area in fig. 21 are shown in fig. 24. These soils have uniformly light tones and usually are associated with termite mounds recognizable by individual or isolated small stands of trees in the rice fields. Small "islands," representing remnants of karst ridges in the later stages of the erosion cycle, are recognized by their association with the karst area, as shown in the middle left of fig. 21 and also in the bottom of fig. 24. These islands are usually tree-covered.

b. Contributing elements. Infrequent occurrence of standing water and flowing streams indicates good relative soil permeability.

c. Genetic description. These soils are related to development of karst topography in a humid environment.

d. Factor estimate reliability. Karst areas with sinkholes and ridges can be identified 100 percent of the time. Lop Buri alluvial apron soils and residual islands can only be identified by association with karst patterns in an area.

43. Appearance on ground. A monotonous repetition of ridges (residual soils) and sinkholes (colluvial soils) typifies the terrain. Fig. 25 is a ground photo of a cross section through a sinkhole channel and two ridges from which the surface soil has been removed. Fig. 26 shows sample sites 59 (in the bottom of a sinkhole) and 60 (on a ridge) which are indicated in figs. 21-23. The soils of the ridges have white limestone gravels on a black surface, whereas the jet black sinkhole surface soils have little or no gravel. This is true also for the karst "island" soils and alluvial apron soils shown in figs. 27 and 28, respectively.

44. Dimensions. Soil sample data for a sinkhole colluvial clay and an adjacent karst ridge residual clay (sample sites 59 and 60 respectively) are given in table 2. The textures of these soils are similar except that the residual soils have higher percentages of coarse particles. The sinkhole soils are comparatively more plastic and have higher moisture contents and organic contents than the ridge soils.

45. Relation to other factors. Vegetation provides an important indicator of soil moisture and drainage condition.

46. Regional distribution. See Pendleton's map of Thailand soils (fig. 2).

Chiang Mai loam

47. These are Recent alluvial soils representing flood deposits in mountain valleys.

48. Recognition on air photos.

a. Appearance. Figs. 29 and 30 are, respectively, a mosaic and stereopair of alluvial apron soils located about 2.5 miles northeast of Chiang Mai in the Chiang Mai valley. The mosaic in fig. 31 and stereotriplet in fig. 32 are of the alluvial floodplain soils at Lamphun along the Nam Mae Kuang, a parallel tributary of the Mae Nam Ping, the major river of the Chiang Mai valley. The soil in both areas is Chiang Mai loam and its indicators are: (1) rice cultivation, (2) uniform light tones, and (3) association with major surface drainage features.

b. Contributing elements. The pattern represents mountain valley floodplain type deposits where deposition of the sediments is not far removed from the source. High volume and high velocity flows predominate during flood periods. This implies processes of origin (transportation and deposition by water) which are important in identification and evaluation of alluvial deposits.

c. Genetic description. These soils are Recent alluvial soils representing floodplain deposits in mountain valleys.

d. Factor estimate reliability. The indirect indicators and associations mentioned in a and b above suggest approximations which will be correct more than 50 percent of the time for soil texture. The reliability will increase rapidly with additional combinations of field and photo pattern experience in an area.

49. Appearance on ground. The surface is nearly level and almost always cultivated in rice.

50. Dimensions. Ground data for the sample sites shown in figs. 29 and 31 are presented in table 2. These data show that most of the soils sampled were lean clays.

51. Relation to other factors. None.

52. Regional distribution. See Pendleton's soil map of Thailand (figs. 2-5).

Chanthaburi clay

53. Pendleton identifies the Chanthaburi clay as a true laterite soil, extremely high in clay content and containing practically no sand. He further states that the parent material is a basic igneous rock which hardened from a molten magma so low in silica that no quartz separated out on cooling.[4]

54. Recognition on air photos.

a. Appearance. Figs. 33 and 34 show soil sample sites in the Chanthaburi clay area about 7 miles east and northeast of Chanthaburi. The air-photo indicators of this soil are: (1) a landscape composed of ridges between large erosional gullies which generally radiate from the highest elevation, (2) light-toned soil surfaces and minor vegetation (grasses, etc.) and dark-toned tree vegetation, and (3) small, rectangular patterns of land use. Uniformity in land use occurs only in the major erosional gullies where rice is grown and on the ridges where large rubber plantations are found. There are a few isolated low hills on the ridge tops.

b. Contributing elements. Delineation of this soil on air photos is not difficult because of the contrast in patterns of the Chanthaburi clay with those of adjacent soils. This can be seen in figs. 33 and 34 in the area generally north and west of sample site 146 and also in the lower left of fig. 33.

c. Genetic description. These are residual laterized soils derived from basic igneous rock.

d. Factor estimate reliability. With the above-listed indicators, this soil can be identified correctly 100 percent of the time.

55. Appearance on ground. A diversity of natural slopes is typical of this area. The level surface in the vicinity of the local airfield (the light-toned clearing north of sample site 149 in figs. 33 and 34) is shown in fig. 35. This area is a major portion of a large ridge with very shallow north slopes. Smaller ridges have steeper slopes. Large erosional gullies, planted in rice, will also be nearly level. The tops of some of the ridges are marked with isolated peaks or hills.

56. Key to the identification of these soils on the ground is the uniform iron-red color of the surface and subsurface soils. The ridge soils in general are friable, uniform, silt-like materials with a crumb structure, as shown in fig. 36. These soils become very sticky when wet. The structure is responsible for the characteristically good permeability. Sand is found in the profile in significant amounts. The only tangible evidences of rock in the area are small fragments on the slopes of the few isolated hills mentioned above.

57. Dimensions. Table 2 lists a number of USCS soil types which reflect generally a relation between landscape and soil type within the area of Chanthaburi clay. Sample site 146 is in the transition zone between the sand-clays to the north and the Chanthaburi clay, with the soil type being sandy or lean clay. Sites 147 and 152 are located on rice-cultivated terraces where alluvial sorting has resulted in a lower accumulation of fine soil particles in the soil profile, producing low plastic soils. The remaining sample sites are high in clay content and are classified as heavy clay or silty clay. These latter soils are more representative of the Chanthaburi clay as described and mapped by Pendleton.

58. Relation to other factors. Rubber trees and fruit trees are found on these soils.

59. Regional Distribution. See Pendleton's soil map of Thailand (figs. 2 and 4).

Natural levee

60. Natural levees result from sediment deposition adjacent to a stream channel during flooding. Although they occur to some extent along all flooding streams and rivers, they are extensive and easily discerned in the Central Plain.

61. Recognition on air photos.

a. Appearance. In the northern portion of the Central Plain the natural levees are easily discerned by (1) the density of termite mounds, and (2) the proximity to present and former channels. In the southern portion of the Central Plain, natural levees are easily recognized along present and former river channels because they obscure the pattern features of the older Bangkok soils.

Fig. 37 shows the levee soils adjacent to the Mae Nam Pa Sak at Sara Buri. At this photo scale the density of termite mounds in the vicinity of the river appears uniform and suggests the extensive levee deposits in the area. The upper left and lower right of this illustration show a noticeable reduction in the number of mounds per unit area. The abandoned channel, which is annotated in fig. 37, is easily seen because of termite mounds on the adjacent natural levee soils. Fig. 38 shows sample sites on a river terrace and a natural levee at a comparatively large photo scale. Small-scale aerial photography is of greater value than large-scale photography in delimiting patterns of levee soils, as is shown in fig. 39 where the levee boundary has been delineated on one photograph.

b. Contributing elements. A preliminary study of regional surface drainage channels and adjacent soil types allows assessment of natural levee development in an area.

c. Genetic description. The soils are sediments deposited in levee form along the flanks of channels during periods of flooding.

d. Factor estimate reliability. Chances for correct identification of natural levees on air photos with the above indicators are near 100 percent.

62. Appearance on ground. The slope of the ground surface away from the channel is hardly perceptible to the eye, yet there are rivers

in Thailand where the surface of the water in the channel is above the elevation of the surrounding land and the water is confined within the channel by the natural levees on either side. Ground photographs at sample sites 19 and 20 are shown in figs. 40 and 41. Note the termite mounds with trees on the levee soils in fig. 41. Fig. 42 shows paddy development on the levee top near the riverbank at sample site 17.

63. Dimensions. Ground data for sample sites indicated in fig. 37 are given in table 2.

64. Relation to other factors. Termite mounds, which are usually identified on aerial photography by the associated vegetation, provide a valid indicator for delineating levee soils in some areas; however, judgment must be used since termite mounds are also found in other soils.

65. Regional distribution. Natural levees are found adjacent to all major river and stream channels in Thailand which are or have been subjected to frequent flooding.

Beach ridge

66. Low ridges of water-sorted materials, usually sandy, which mark the shorelines at present and former levels of large water bodies are known as beach ridges.

67. Recognition on air photos.

a. Appearance. The important pattern indicators of beach ridges are: (1) an arrangement of several linear or curvilinear low ridge forms, (2) white tones of the highly reflecting sands which compose the ridges, (3) dark tones of swale depressions between the ridges, usually containing vegetation or standing water which contrasts with the ridge features, and (4) location of village platforms, home sites, and roads on the ridges (but rarely in the swales). These indicators can all be seen in figs. 43-45.

b. Contributing elements. These features are associated with present or former shorelines of seas or lakes. Sand is the predominant material in beach ridges. Beach ridge soils are too well drained for rice or rubber cultivation but are excellent for coconut, fruit trees, and dry garden crops.

c. Genetic description. These soils are the result of wave and current activity along the shores of large bodies of water.

d. Factor estimate reliability. Beach ridges can be distinguished 100 percent of the time when the above indicators are present.

68. Appearance on ground. The low ridge-like landforms with their attendant vegetation are in great contrast with the vegetation found in the lineal depressions (swales) between the ridges. Leached white or brown-white sands are found everywhere on the surface; figs. 46-48 illustrate the high reflectance of these sandy soils.

69. Dimensions. Ground sample data are presented in table 2. Sample site 122 is located along the coastal beach about 10 miles south of Chanthaburi, and from the data sheets it is seen that the beach soils have the same general properties as the beach ridge soils at sample sites 123 and 134. The sands at site 133 have a small percentage of fines. This is believed to be due to mixing with soils from the lower tidal mud flats.

70. Relation to other factors. As mentioned above, the relatively high permeability of the sand soil of the beach ridges is ideal for coconut and other fruit trees, as well as dry garden farming, but is not suitable for rice and rubber cultivation. The ridge and swale complex is repetitive in nature and is a significant surface geometry feature.

71. Regional distribution. Beach reaches are found adjoining the Gulf of Siam.

Abandoned channel

72. Abandoned river channels are frequent and conspicuous features in the Central Plain, and they also occur throughout Thailand. Sometimes the terrace and floodplain soils within the channel will be of different types from the soils surrounding the channel. Usually the channel soils will have higher moisture contents than adjacent soils.

73. Recognition on air photos.

a. Appearance. Former river channels, now having little or no water flow, are easily discerned in the Central Plain. Their indicators are: (1) river channel configuration associated with meanders, oxbows, and distributaries, (2) natural levee remnants often having home sites and trees along portions of the channels, (3) paddy-dike systems in the channels differing from the systems of the adjacent areas, and (4) in the northeast section of the Central Plain, there are termite mounds on the natural levees but none in the channels. Fig. 49 is an air-photo mosaic of an abandoned channel as it appeared in January 1953 and fig. 50 shows the same channel in December 1964. A stereopair of this area is shown in fig. 51. Another mosaic of an abandoned channel is shown in fig. 37.

b. Contributing elements. Abandoned channels can usually be traced to the present water channel and in many cases deductions can be made as to the reasons for channel diversion and blocking.

c. Genetic description. The soils are related to deposits in erosional channels of former streams or rivers.

d. Factor estimate reliability. Correct identification of the feature can be accomplished in almost all cases.

74. Appearance on ground. Figs. 52 and 53 are views overlooking the sample points indicated on the air photos. Often the ground view is characterized by such features as levees, terraces, and flat-bottomed channels. Rice is almost always grown in the channels where there is usually more water than on the soils adjacent to the channel. Although the abandoned channels are easily discerned in air photos, it is often difficult to find the smaller and shallower channels on the ground.

75. Dimensions. Sample data for the sites indicated in the air photos are given in table 2. Sample site 12D and 2T15 are in the channel and sample site 89 is located on the soils adjacent to the channel. The data in table 2 show no significant difference between these soils. No moisture samples were obtained, but the channel soils would undoubtedly have higher moisture contents.

76. Relation to other factors. During periods of high water, abandoned channels become significant hydrologic geometry features, and during periods of extreme dryness, they may become significant surface geometry features.

77. Regional distributions. Abandoned channels occur throughout Thailand in areas of alluvial sediments.

## PART III: SURFACE GEOMETRY

78. Surface geometry is concerned with the geometrical configuration of the earth's surface; i.e. its actual physical shape, size, and arrangement. It includes such features as steep slopes (hill and mountainsides, valley walls, etc.), ravines, embankments, ditches, plowed fields, boulder fields, termite mounds, rice field dikes, and many others. Since a vehicle encountering any one of these features reacts to a three-dimensional situation, it follows that a rigorous description of the surface must be obtained if the terrain parameters required for mobility analysis are to be recoverable. Unfortunately, at the present time, there is no satisfactory mathematical method for quantitatively describing or classifying surface geometry for mobility purposes; therefore, simple cross-sectional profiles and areal and regional slope measures are used as the best methods for recording actual surface irregularities. It has been found that these measurements, if given in sufficient detail, are adequate to permit the recovery of the necessary terrain parameters. These parameters are: slope, step height, approach angle, and spacing of vertical obstacles. The principal sources of published information used in this portion of the study are references 4, 7, 8, and 9 in Literature Cited.

### Selection of Examples

79. This portion of the catalog presents a grouping of terrain features that form distinctive patterns pertinent to surface geometry. Each pattern is composed of repetitive assemblages of those attributes of a surface that give the pattern homogeneity and "character." Because of the widespread occurrence of the paddy/dike complex in Thailand and the importance of dikes as mobility obstacles, a major portion of this section is devoted to patterns caused by their presence. A total of 14 surface features are presented in this section, of which nine are concerned with the design and arrangement of rice paddies, two with boundary dikes, one with mountain valleys, one with karst topography, and one with termite mounds. All but two of the examples are from the Lop Buri study area. The other

two are from the Chanthaburi and Chiang Mai study areas.

80. Hasty examination of air photos of extensive dike complexes may create an impression of chaos in the organization of the landscape in terms of size, shape, and arrangement of paddies. Closer examination suggests an organization of the landscape that is systematically adjusted to one or more of the following four important factors: (1) topography, (2) water source and availability, (3) traditional land-use practices, and (4) the impact of modern, highly organized agricultural practices. In flat areas paddy shape and arrangement may reflect either traditional or modern cultivation and water control practices. The pattern reflecting the traditional practices is composed of small-sized paddies of varying shape and arrangement. The pattern reflecting modern practices is composed of parallel systems of rectangular paddies adjusted to an efficient water distribution system. Also, paddies in flat areas are larger than those in areas with any relief, no matter how slight. Everywhere but the very flat areas, rice paddies vary in elevation and planimetric arrangement in conformance with the shape of the terrain. Conformance with the terrain is, in fact, one of the most important characteristics of paddy systems, and it is given considerable emphasis in the discussions. The main dike characteristics related to topography are average dike asymmetry (which increases with increasing terrain slope) and dike spacing.

81. From a mobility standpoint the most important dike characteristics are size and shape and frequency of occurrence. Frequency can be determined from air photos with ease, but the accurate determination of dike dimensions requires large-scale photographs and the application of photogrammetric techniques. Many of the factors which contribute to dike size are not readily apparent in air photos, and inferences must be relied upon for qualitative aspects of the analysis. Some of these subtle but important factors are hydraulic considerations related to seasonal rainfall and topography, practices of the rice farmer, and age of the dikes. The influence of age on dike size is exemplified by the practice during the planting season of disposing of clumps of mud and weeds by piling them on top of the nearest dike. Obviously, the older a dike is the more it has been subject to this form of growth. Also, some dikes are used as

footpaths, and such dikes may be larger than others in the area.

82. The surface geometry features included as examples in this catalog are as follows:

- a. Terraced paddies
  - (1) In narrow mountain valleys
  - (2) On local transition slopes
  - (3) On regional slopes
  - (4) On side slopes of abandoned stream channels
  - (5) On stream valley sides in flat areas
  - (6) On natural levees
- b. Paddies with random arrangement
  - (1) On slightly undulating terrain
  - (2) On flat terrain
- c. Paddies with systematic parallel arrangement on flat terrain
- d. Boundary dikes
  - (1) In abandoned channels
  - (2) On tidal flats
- e. Mountain valleys
- f. Rolling karst terrain
- g. Termite mounds

## Data Collected

83. A summary of surface geometry data illustrated in this portion of the report is presented in table 3. The table includes original field site numbers, location, date of sample, and references to figures showing dike plan and cross section and to photo illustrations.

## Description of Catalog Examples

### Terraced paddies in narrow mountain valleys

84. The Thai almost never terrace the steep-sloping high valley sides as is a practice in neighboring countries. In Thailand, valley

terracing is often discontinuous, but when it does occur it is confined to the lower and less rugged portions of mountainous and hilly terrain. Paddy terracing in narrow mountain valleys can significantly contribute to the accessibility of summit areas from a mobility standpoint. The terraced paddies considered in this section are situated in a mountainous region about 8 km southeast of Sara Buri on the road to Wat Phra Chai. The site is SG-9.

85. Recognition on air photos.

a. Appearance. The only terracing of any significance within the area shown in fig. 54 is that indicated at two places along the road which follows the thread of the valley. The relation between the paddy area, the mountain valley, and the surrounding area is shown in fig. 54. Details of the terraced paddy area and the configuration of the valley are shown in fig. 55. The paddies are systematically organized into longitudinal and transverse terracing with respect to the axis of the valley. The terraced paddies appear as light-toned areas standing out in sharp contrast to the surrounding patterns which are related to field crops on the valley floor and timber on the valley sides. The striking contrast between the highly organized paddy system and the surroundings is the dominating aspect of pattern identity. At the scale of the photos shown, the terracing is only slightly perceptible when studied in stereo. Individual dikes can be seen as minute lines which bound individual paddies.

b. Contributing elements. The major contributing elements are topographic position in the valley, boundary conditions which separate the dike complex from the surrounding area, and diversion of natural drainageways around the paddy areas.

c. Genetic description. The occurrence of terraced rice paddies in narrow valleys is generally dependent upon the availability of water in the valley and upon the availability and accessibility of land suitable to the cultivation of rice. Since such areas are probably the last to be developed for wet rice farming, it is doubtful that they would be developed extensively except in areas of very high population density.

d. Factor estimate reliability. Determination of the identity and areal extent of terraced paddies in valleys in mountainous areas can be accomplished with ease, even by someone with little field experience. For patterns of this type, with good quality photographs at suitable scales, the reliability factor for the qualitative aspects of analysis might be as high as 90 percent with experience and critical examination of photos. Quantitative information related to elevation differences

between paddies and the asymmetry of dikes cannot be obtained from the photos available for this study.

86. Appearance on ground. On the ground, the terracing of the paddies in this area is obvious. It is, in fact, one of the classical examples of terracing in this text. The stereopairs in figs. 56 and 57, whose orientation is shown by the arrows in the sketch in fig. 55, are ground views of terraced paddies in the narrow valley at site SG-9. Since these ground photos were taken shortly after planting, the terrace steps and the dikes can be seen clearly.

87. Dimensions. Primary dikes in these circumstances may approach heights of 4 to 5 ft and have an asymmetry of 2 ft or more. Secondary dikes in such a terraced arrangement may be no larger than some of the smaller dikes found in flat areas. Because of this variability in the case of sporadic patches of such paddies, it is probably necessary to examine each case individually.

88. Relation to other factors. Under conditions of high rainfall and maximum flow in the stream there may be a relation between the paddies adjacent to the stream and the stream itself. In such an instance the border dikes would define the streambank configuration for the hydrologic geometry factor family. This condition would persist as long as the boundary dikes function as streambanks. During periods of severe runoff and flow, erosion may destroy the boundary dikes and remove portions of paddies subjected to moving water.

89. Regional distribution. The extent of valley terracing similar to that described above is unknown. In Thailand, valley terracing in general can be expected to occur in association with the lower and less rugged portions of mountainous and hilly terrain, floors and low side slopes of the broad intermontane valleys, and the floors and low side slopes of very broad, gently sloping valleys of the plateau.

## Terraced paddies on local transition slopes

90. In areas of intensive wet rice cultivation the paddies extend part way up the lower slopes of hills and mountains. Transition slopes are of considerable importance to mobility in wet rice areas because of

the occurrence of paddy terracing as well as the natural slope of the terrain. There are two general transition slope categories which are of importance to this study: (1) broad regional slopes of considerable areal extent flanking major elevated land masses (see page 28), and (2) local, often abrupt, slopes between a local highland and an adjacent lowland. The second category is the subject of this pattern analysis. The area selected to illustrate this condition is situated about 16 km south of Sara Buri and about 4 km east of Ban Hin Kong. The study site is SG-65.

91. Recognition on air photos.

a. Appearance. A marked linearity, almost to the degree of parallelism, characterizes the photo pattern of this feature. The systematic parallel arrangement of the paddies which occupy the long narrow transition slope is the dominating element of the pattern. Figs. 58 and 59 show how the pattern persists throughout the length of the transition slope zone at the base of the mountain. It pinches out near the west end of the mountain. The terraced paddy zone is bounded on the uphill side by the dense timber which occupies the steep slopes of the mountain. It is bounded on the lower side by a change in paddy layout from parallel to random.

b. Contributing elements. The supporting or indirect elements of the analysis are largely in the form of inferences which can be drawn from the more subtle aspects of the pattern. For example, at the scale shown in fig. 58, critical stereo study of the original 1:15,000 photos reveals very slight vertical rises between paddies. Detailed study of the original 1:5,000-scale photos in stereo results in obtaining a clearer perception of the vertical rises between the paddies. However, it is pointed out that the 1:5,000 photos were taken after harvest and the paddy floor could be seen in each instance. Other supporting inferences are uniform tones throughout the zone covered by the systematic paddies, parallel dike lineation whose spacing often decreases toward the upland, and change to more random paddy shapes and sizes in the lower area below the transition zone. There is one other aspect which may be significant--there are more termite mounds on the transition slopes than on the adjacent lower and wetter areas.

c. Genetic description. The occurrence of terraced paddies on transition slopes is generally dependent upon the availability of water which, in this instance, is supplied from above by runoff. Inundation of individual paddies is believed to be accomplished by traditional paddy-to-paddy gravity flow during periods of high rainfall since

there are no indications of an organized irrigation system. The upper boundary marks the upper topographic limit for lowland wet rice agriculture in this area. The rate at which wet rice farming advances uphill in transition slopes is not known. However, in this area, as in similar areas, there are indications that this type of land utilization is on the increase. In the example shown, detailed stereoscopic study reveals recent inroads into the adjacent timber evidenced by clearing along the more favorable contours above the present paddy zone.

d. Factor estimate reliability. The identity and areal extent of terraced paddies along transition slopes such as these can be determined with ease, even by someone with little field experience, and therefore the reliability will approach 100 percent. The remainder of the qualitative aspects of the analysis is assigned a lower reliability factor because of the many inferences which must be drawn from the subtle associations present. Quantitative information cannot be obtained from the photos available for this study.

92. Appearance on ground. Appearance on the ground is highly dependent upon the rice growth stage. When the rice "tops" the dikes the view from a passing automobile is not one of orderly terraced arrangement. The ground photo in fig. 60, taken before the rice had reached maturity (17 September 1964), clearly illustrates this problem. The ground photo is a panoramic sweep from the highway on the left (south of the area) looking generally west to northwest. Critical study of the midportion of this ground photo (in stereo) reveals the successive rises between adjacent paddies. Characteristics of the dikes cannot be seen in the photo because of the rice.

93. Dimensions. Random cross sections taken at site SG-65 determined the dike sizes as shown in the sketches which have been overprinted on the air-photo stereopair in fig. 59. Each dike can be located in the accompanying insert plan sketch. The sketches clearly show the uphill progression of the terracing at the sample site. Note the asymmetry of the dikes.

94. Relation to other factors. The soils in the transition zone are believed to be colluvial deposits which originated on the higher slopes above. It is quite likely that the combination of fine grain texture and possible seepage zones below the surface might result in instances of instability with respect to mobility. There are no hydrologic geometry

relations since there are no canals bringing water to the area.

95. Regional distribution. Transition slope terracing may be found wherever intensive wet rice cultivation is practiced. It is widespread in the Lop Buri/Sara Buri area along the side slopes of the rock outliers from the adjacent plateau to the east.

Terraced paddies on regional slopes

96. This discussion is concerned with paddy terracing which occurs on very broad slopes, regional in nature, which flank major elevated land masses (figs. 61 and 62). The selected pattern is representative of the broad slope separating the massive limestone hills near Lop Buri from the broad natural levee of the Mae Nam Pa Sak. The study site, SG-81, is about 9 km north of Sara Buri on the highway between Sara Buri and Lop Buri.

97. Recognition on air photos.

a. Appearance. The dominating element of the pattern is the highly repetitive organization of groups of random shaped paddies aligned along the contour cf the slope. To the uninitiated, this arrangement may appear quite subtle, but critical study does reveal an organized linearity in the systematic paddy arrangement. Paddy sizes and shapes vary only slightly, indicating the general uniformity of slope. The continuity is broken in places by groups of large paddies which occupy low areas believed to be associated with channels which once crossed the area. The direction of slope is indicated in fig. 61. The slope of the area is so slight that it is not indicated by stereo study of the photos used.

b. Contributing factors. That this feature is situated on a broad regional slope is further indicated by the general parallelism which exists between the drainageways which cross the area. Two of these are shown in fig. 61. These two channels are marked by dense tree and brush cover which borders the watercourses. Detailed study of other drainageways in the area (to the west of the mosaic in fig. 61) shows the capture of many drainageways by a highly organized paddy/dike system in an attempt to utilize all of the natural runoff. The presence of termite mounds also suggests sloping ground and freedom from long periods of inundation.

c. Genetic description. In the Lop Buri/Sara Buri area this situation occurs on slopes related to the building of broad alluvial fans or alluvial outwash aprons outward from the

base of a highland mass. The upper portion of the regional slope is more complex and it is believed to be related to pedimentation processes. On a regional basis this slope is in transition between the highlands (mountains and plateau) and the very broad Bangkok Plain. Land-use practices are closely adjusted to the terrain with respect to size, arrangement, and grouping of paddies and dike asymmetry.

d. Factor estimate reliability. Since the area is so extensive, the slope so gentle, and the indicators of terracing so subtle, identification as terraced paddies in similar situations might range between 75 and 90 percent depending upon the experience and the degree of closeness of examination. At the scale of the original photos used (1:15,000) the quantitative characteristics of the dikes cannot be obtained from photo study.

98. Appearance on ground. Only the most discriminating eye can detect terracing from a ground position on this slope. This difficulty is clearly shown by critical study of figs. 63 and 64. The photo in fig. 63 is taken looking along dike B to the east. Thus, the dike to the left is on the north and the one to the right is on the south. Even though the dike is quite large, the floor of the paddy to the left appears to be higher than the one to the right. This is verified by the cross section shown for dike B in fig. 65. In fig. 64 terracing is rot apparent from the ground. The ground photos were obtained before the rice had topped the dikes.

99. Dimensions. Field examination showed a general step increase of 2 to 6 in. per paddy as indicated in fig. 65. The dikes in this area are broad, varying in width from 41 to 65 in. at the base and from 20 to 37 in. at the crest.

100. Relation to other factors. Soils in this area are silt and silty clay. They are annually replenished by suspended sediment (silt and clay) brought from the higher areas by direct overflow and deposited in the slightly lower areas adjacent to the drainageways, and by the gravity feed distribution system from paddy to paddy on the remainder of the slope. Vegetation and hydrologic geometry are not significantly related to surface geometry except along the streams.

101. Regional distribution. This type terracing is extensive in the

peripheral region of the Bangkok Plain. It is well developed in the Sara Buri area in the region a few miles north of Lop Buri.

Terraced paddies on side
slopes of abandoned stream channels

102. The terracing related to the side slopes of channels is of significance to mobility because of the rises between the successive paddies, the general dike asymmetry, and the often abrupt natural gradient of the side slopes. The patterns exhibited by the two conditions--with and without a principal stream--are sufficiently different to require separate treatment in this catalog. In the area under consideration, the terraced paddies are related to the side slopes of abandoned channels and meander scars. This condition is illustrated in an abandoned channel near the Siam Cement Company (site SG-117) west of Sara Buri near Ban Wiang (figs. 66-68). Part of this channel is occupied by a small lake. A supplementary pattern, illustrated in fig. 69, represents an abandoned channel of considerable length southwest of Sara Buri and about 8 km west of Ban Hin Kong.

103. Recognition on air photos.

a. Appearance. Critical examination of the aerial mosaic in fig. 66 and the vertical photo in fig. 67 clearly reveals the terraced situation related to the old channel and lake-bed area. The most outstanding indicator of terracing is the systematic adjustment of paddy plan to the side slopes which bound the channel and the lake. When figs. 67 and 68 are examined in stereo, the terracing is clearly discernible. The pattern illustrated in the supplemental stereophoto (fig. 69) is characterized by a drastic change in paddy design between the channel and the adjacent higher surface. When examined in stereo, the elevation difference between the two surfaces can be seen clearly. In both examples the dominating element of the photo pattern is a systematic lineal paddy plan adjusted to the side slopes of the channel.

b. Contributing elements. Indirect indicators of terracing are subtle and can help establish tentative conclusions as to the characteristics of suspected terracing. In fig. 66, there are indications that topographic continuity once existed between the channel and lake area, and that the continuity was interrupted--perhaps by levee building of the Mae Nam Pa Sak and later by the activities of man. In the area shown in fig. 69 the entire portion of the channel

area is utilized for rice farming. Scattered termite mounds occur on the terraced paddies in both instances but not on the floor of the channel. The absence of termite mounds in the areas outlined and marked "channel" is believed to be significant in suggesting a lower topographic position, higher moisture content, and perhaps higher percentage of clay in the soils.

c. Genetic description. The terracing shown in fig. 66 is believed to be related to such factors as stream capture, levee building, and the efforts of man. The features of the pattern imply that levee building activity on the Mae Nam Pa Sak may have cut across an old stream channel, blocking the flow of water. It also appears that this alteration of the landscape was finally completed by man through many generations of attempting to utilize the sloping lands in rice farming. In the example in fig. 69, the channel representing a former stream appears to have its origin many miles to the north; constant alteration of the landscape by man has resulted in the capture of the stream and its effective obliteration from the landscape.

d. Factor estimate reliability. The reliability for determination of the identity and areal extent of paddies in this configuration is rated as high as 90 percent. Quantitative determinations cannot be made from the photos used.

104. Appearance on ground. Terracing related to abandoned channels is usually a striking feature of the landscape, largely because of the relatively great local elevation difference between the flat plain and the channel floor below the surface of the plain. The ground views in figs. 70 and 71 clearly show the paddy terracing on the side slopes of the old stream channel at study site SG-117.

105. Dimensions. Field data were not obtained at this study site.

106. Relation to other factors. Soils vary from clays in the floors of the channels to silty clays along the sides and predominantly silty soils in the natural levees where they occur. A hydrologic geometry relation would exist during periods of flooding. During such a period, the outward dikes would be in contact with the floodwater, thereby forming the bank of the water-filled channel.

107. Regional distribution. The flat area of the Bangkok Plain and the lower reaches (lesser slopes) of the broad regional transition slopes are marked with numerous abandoned channels which are lined with paddies

in systematic terrace organization. Where major streams have built levees along the banks of the channel, numerous oxbows and abandoned lakes occur; however, these features are usually associated with extremely flat terrain and not the broad regional slopes.

Terraced paddies on stream
valley sides in flat areas

108. The second major type of paddy terracing related to channels in an otherwise flat area occurs on the valley sides of an active stream crossing an area in its own small valley system. Terracing of this type is of considerable significance to mobility because of the critical condition during periods of flood when moving water occupies the entire floor of the channel and is confined by the paddy dikes of the side slopes. The pattern in this example (near site SG-105) is associated with a small stream at Ban Khok Yai about 18 km south of Sara Buri in the valley system of Khlong Nong Khae.

109. Recognition on air photos.

a. Appearance. The dominating aspect of this pattern is close adjustment of the organized system of dikes to the slopes on either side of the stream valley and one cutoff valley (figs. 72 and 73). This is clearly indicated by the sharp contrast in paddy plan between the systematic arrangement of paddies related to the valley walls and paddies occurring on the valley floor and on uplands away from the influence of the valley. For example, note the difference in paddy size, shape, and organization between terracing on the inside portion of the channel bend, the outside of the channel bend, and the straight portion of the channel. The change in elevation between paddy surfaces can be seen in the stereopair in fig. 73.

b. Contributing elements. While the direct indicators discussed are the most obvious for pattern identity, there are a few elements of the analysis which are indirect and can be used to obtain further information about conditions within the pattern area. The lack of termite mounds in the floodplain of the stream valley and in the floor of the cutoff valley suggests high moisture and perhaps inundation at times. There are termite mounds on the paddies in terrace position. The highly irregular nature of the paddies on the floor of the valley in terms of size, shape, and arrangement suggests an element of change, perhaps related to seasonal flooding and damage. There is evidence of active bank erosion along some of the channel bends which suggests occasional loss

of dikes and possibly of entire paddies. The significance of this is the possibility of highly unstable conditions during periods of flood.

c. Genetic description. This feature is related to an active stream which forms one of the major water escape routes from the broad slopes which form the middle to upper portions of the Bangkok Plain. The stream appears to have changed its course many times throughout its path length across the plain. The study area, site SG-105, appears to be located in a cutoff tributary. Photos taken in 1953 and again in 1965 show the main watercourse to be in the channel to the west. However, there are ample indications that this situation may be momentary and that further shifting between channels is likely to occur. It is quite possible that the stream occupied the channel to the east at the time the village of Ban Khok Yai was founded because of the necessity of transportation. Detailed study of the upper part of the stream channel in the vicinity of Sara Buri suggests that the entire stream system may predate the levee building of the Mae Nam Pa Sak.

d. Factor estimate reliability. There is no difficulty in making the determination that terracing occurs on the side slopes of the valley which contains the stream. Reliability of this aspect of the analysis might be as high as 90 percent when high-quality photographs of suitable scale are used. That portion of the analysis which is concerned with the inferences related to the dynamic character of the stream is rated lower. For the uninitiated, this might be 0 to 10 or 20 percent, and for some one with experience and a discriminating eye as high as 80 percent. Quantitative information cannot be obtained from the photos used.

110. Appearance on ground. Figs. 74 and 75 were taken in the vicinity of site SG-105. The terracing in fig. 74 is on the midslopes of the valley side and in fig. 75 is below the upper portion of the slope of the valley side. Note the termite mounds in both photos. Terracing is readily apparent along the sides of this valley when viewed from the ground position. However, the very important variations in paddy plan throughout the terrace zone are not as apparent from ground vantage point as from aerial viewing.

111. Dimensions. As indicated on the sketch showing paddy plan and dike cross sections (fig. 76), the primary dikes are asymmetrical and paddy elevations differ by 6 to 9 in. The sketch clearly indicates direction of terracing downward from dike D to dike A.

112. Relation to other factors. This situation undoubtedly has a wet weather or flood relation to the hydrologic geometry factor family. This relation would become increasingly significant with increasing depths of inundation over the floor of the valley. Upon inundation of the channel floor, the dikes of the terraced paddies would come in contact with the water surface and the outward dikes would become the channel banks for a hydrologic geometry feature. Regarding soils, the stream valley is incised into silty clay soils of the Bangkok Plain (CL). (See page 9 for a description of the soils in this area.)

113. Regional distribution. This pattern, with considerable variation, extends southward from the vicinity of Sara Buri to the intersection with Khlong Raphiphat, a distance of about 22 km. The upper few kilometers of this stream valley (between Sara Buri and Ban Pha Phai) present the greatest variation because of the almost complete absence of a stream.

## Terraced paddies on natural levees

114. In areas of intense wet rice cultivation, natural levees of streams are utilized as well as the flat areas, but only through the use of terraced paddies. Two general types of terraced paddy patterns associated with levees are discussed in this section: (a) the broad levees associated with the Mae Nam Pa Sak in the Central Plain, and (b) the narrow levees associated with smaller streams in the intermontane valley in the vicinity of Chiang Mai. The example locations in the Central Plain (sites SG-115 and SG-116) are on the broad levee on the south banks of the Mae Nam Pa Sak 12 to 13 km west of Sara Buri. The example location in the vicinity of Chiang Mai (site SG-41) is northeast of Chiang Mai.

115. Recognition on air photos.

a. Appearance. Near sites SG-115 and SG-116 the paddies are arranged in a parallel system which is generally perpendicular to the direction of the streamflow (fig. 77). This arrangement becomes the dominating aspect of the pattern. This is best illustrated in the area along the road between sites SG-116 and SG-115 south of the river. In fig. 78, the lineal arrangement of the system can be seen at a larger scale. In this region the levee varies from 2 to 4 km in width (including both sides of the river). The border is reflected by the contrast in paddy plan between the

levee and the adjacent flat area to the south.

The levees which occur in the intermontane basin in the vicinity of Chiang Mai (fig. 79) are related to streams which are small and which have a rather steep gradient throughout their length between the mountains and the main stream occupying the valley. The levees on either side of the streams are narrow and not many feet higher than the surrounding terrain and the paddies are terraced accordingly. In fig. 79, because of the small scale of the photo, the paddy plan is difficult to see. However, critical examination reveals that paddies are generally arranged in parallel systems along the contour.

b. Contributing elements. Other significant aspects of the photo pattern associated with the levee in fig. 77 are high density of termite mounds, light photo tones, and slightly higher topographic position than the surroundings. Fig. 79 (Chiang Mai) must be studied more critically than fig. 77 (Mae Nam Pa Sak) because of the scale difference and because the indicators of levee building and associated terracing are much more subtle. The regional slope in fig. 79 is downward to the southwest as indicated by the directional trend of the streams. The streams are marked by long village platforms and trees throughout a great portion of their length. There is a considerable variation in tones and a subtle streaked linearity exists parallel to the general direction of the streams. These tones may be related to soil and soil moisture content differences. It is suggested from this arrangement that the lighter toned areas are slightly higher than the darker toned areas and that many of the lighter areas are associated with levee building activity. In some instances the highways are located on the narrow levees.

c. Genetic description. The levees described are related to deposition of sediments along the banks of overloaded streams as they flow across a flat area. Near sites SG-115 and SG-116, the Mae Nam Pa Sak has built an extensive levee along its course as it flows from the highlands on the east across a portion of the Bangkok Plain to its junction with the Mae Nam Chao Phraya, the major stream of the plain. The result has been to establish a well-defined topographic border between the low and extremely flat portion of the plain to the south and the very gently sloping portion of the plain to the north.

d. Factor estimate reliability. In the case of the levee system related to the Mae Nam Pa Sak, and to any analogous

situations which reflect similar pattern features, the reliability factor for qualitative description and analysis is quite high, approaching 100 percent for an experienced viewer. Because of the more complex nature of the pattern in the intermontane plain, the reliability factor assigned for qualitative description and analysis might approach 50 to 60 percent, and then only with experience. Quantitative information cannot be obtained from the photos in either area with the scale of photography used.

116. Appearance on ground. On the ground the terracing related to broad natural levees is often difficult to see even though the paddies are terraced in accordance with the slope. This is because the paddies differ in elevation by just a few inches. The terracing which occurs on the small steeper levees is often more obvious on the ground because the paddies are smaller and the step heights are often greater. Figs. 80 and 81 are views north toward the Mae Nam Pa Sak on the upper slopes of the terraced paddy areas at sites SG-115 and SG-116, respectively. In each of these photos terracing is very slight. The height of the rice and the inability to see the paddy floor on either side of the dikes further reduce the impression of terracing from the ground vantage point.

117. Dimensions. Detailed study on the ground revealed some interesting general dike associations with respect to terracing and the type and size of the dike and the direction of the slopes. In both cases the dikes may be grouped into primary and secondary types. The secondary dikes are the shorter ones and they are generally parallel to the stream direction. Dike asymmetry occurs in both the primary and secondary dikes; however, the greater degree of asymmetry occurs in the secondary dikes. This is the response to slope adjustment which in this instance is to the south-southeast. The primary dikes in the example in fig. 79 (site SG-41) are parallel to the stream and lie along the contour. The primary dikes in this instance have a greater degree of asymmetry than those in fig. 77. Field examination revealed that paddy steps differed in elevation by only 1 to 4 in. at sites SG-115 and SG-116 (figs. 82 and 83).

118. Relation to other factors. Because of their generally high topographic position with respect to a stream crest during flood stage, levees are utilized frequently for locations of long village platforms,

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118. Relation to other factors. Because of their generally high topographic position with respect to a stream crest during flood stage, levees are utilized frequently for locations of long village platforms,

highways, trails, and isolated patches of fruit trees and gardens. Thus, there is a relation to vegetation since the village platforms are accompanied by dense tree cover. A more critical relation exists between the paddy/dike complex on the levees and the soils because of the contrast in soil type between the dike surface and the adjacent plains. Table 2 presents data covering soil types on levees.

119. Regional distribution. Levees are widespread throughout the lower and middle portions of the Central Plain and the intermontane plain in the vicinity of Chiang Mai. Variations in levee size and height do occur, but terracing always accompanies the changes in slopes in areas of wet rice cultivation.

Paddies with random arrangement on slightly undulating terrain

120. This situation is one in which the paddies conform to very slight undulations of the terrain. The variation in relief is not great enough to require systematic terracing, and the minor elevation changes that exist are taken up from paddy to paddy by dikes whose asymmetry has no particular orientation. The situation is significant because of the difficulty of identification and prediction of the asymmetrical nature of the dikes when paddies are not organized in systematic arrangement. This pattern is exemplified by site SG-114 which is located on the highway paralleling the south shores of Mae Nam Pa Sak, about 6 km west-northwest of Sara Buri.

121. Recognition on air photos.

a. Appearance. In figs. 84 and 85, the paddies appear as "pieces of a jigsaw puzzle." The dominating aspects of the photo pattern are random size and shape of paddies, highly irregular alignment of dikes, and lack of systematic grouping of paddies.

b. Contributing elements. In this instance, it is necessary to extend the study beyond the limits of the area covered by fig. 84 to determine the extent of the random arrangement and whether there is conformance to any portion of a specific terrain unit. Critical study of the mosaic in fig. 77 suggests such an association with a portion of the Mae Nam Pa Sak levee. Even though the elevation differentials between paddies are too small to be seen in the stereopair in fig. 85, the dike lineations appear to be

in close conformance with the terrain undulations.

c. Genetic description. The genetic tie in this instance is the seemingly meticulous adjustment of each paddy and each dike to conform to the very small surface undulations for purposes of water control. There is sufficient variation in the undulations of the terrain to result in the striking random arrangement of the pattern components.

d. Factor estimate reliability. Indication of this situation is almost entirely dependent upon the ability to distinguish the irregular dike lineation and the random plan for each paddy. Given this condition, together with experience and cognizance of the significance of dike lineation variations, the reliability of identification could probably approach 90 percent.

122. Appearance on ground. In fig. 86, the rice was high enough to conceal all but those dikes in the immediate vicinity of the observer. Under such a condition the identification of the slight undulations is very difficult. In fact, they are often difficult to notice even when rice is absent, particularly if some or all of the paddies are flooded.

123. Dimensions. Both the spacing and the size of dikes vary appreciably, as can be seen even from the small sample recorded in fig. 87. Site SG-114 was selected at random, and it is assumed to be fairly representative of the area. The degree of topographic irregularity can be seen clearly by study of the cross sections of dikes B, C, D, E, and G which enclose one paddy. Dimensions such as these cannot be obtained from the photos used in the study because of the small scale.

124. Relation to other factors. There is no known relation of this particular pattern to patterns of other factors. However, this particular area is on a broad natural levee, and it is quite possible that the slight natural terrain undulations might be affected by the erosional characteristics of this particular soil (clayey silt) when subjected to overflow from the nearby river.

125. Regional distribution. Unknown.

Paddies with random
arrangement on flat terrain

126. In general, the middle and lower portions of the Bangkok Plain are very flat, as indicated by a gradient which is reported to be

1:10,000. Slight breaks in relief occur in the vicinity of the river/levee complexes, abandoned channels, and large, shallow depressions--all related to stream and deltaic activity. In paddy areas not yet influenced by modern methods of mechanized farming and water control, the paddies exhibit a random arrangement in size and shape which reflects the traditional practices of the rice farmer. The only break in this random arrangement is largely one of size of individual paddies as influenced by the topographic undulations discussed in paragraphs 120-125. The pattern selected to represent this feature (site SG-60) lies about 25 km south of Sara Buri.

127. Recognition on air photos.

a. Appearance. The gross appearance of paddies in the flat area shown in fig. 88 is one of complete random arrangement. Paddy size varies in the area illustrated. The study area (site SG-60) exhibits a minor topographic break which is accompanied by slightly larger paddies. The larger paddies are believed to be related to a possible very shallow former channel. A portion of this system can be seen in the middle portion of the large-scale stereopair in fig. 89. Both areas contain paddies which are random in size and arrangement. Those in the slightly lower channel area are larger than those in the surrounding area. The paddies in the lower zone appear to be bounded in places by a boundary dike. Detailed study of figs. 89 (panchromatic film) and 90 (infrared film) shows the striking difference in film response to ground conditions during the time of photography. Both photos were obtained 12 February 1965. (See Part VI: Comparative Photography for a more detailed treatment of the comparison between infrared and panchromatic photography.)

b. Contributing elements. That the general area is flat is indicated by the highly irregular and random nature of the paddies throughout the entire area. Critical examination of fig. 89 reveals several dug waterholes in the area containing the large paddies. There are fewer termite mounds in the area of large paddies than in the surroundings. These two aspects of the pattern suggest a slightly lower topographic position for that portion of the area containing the larger paddies.

c. Genetic description. The genetic relation existing is primarily one of the traditional practices of the rice farmer in a flat area in his attempt to maintain a water level on the rice during the growing season.

d. Factor estimate reliability. The random nature of the paddy can be obtained easily for each situation. However,

the subtle change in paddy plan as adjusted to the slight depression requires very close analysis. When this has been accomplished in conjunction with background knowledge, a higher degree of reliability will result. Quantitative information about dike characteristics cannot be obtained from photos at this scale.

128. Appearance on ground. That the area is flat is clearly indicated in the ground views shown in figs. 88 (insert) and 91. The photo insert in fig. 88 shows the topography in the lowest part of the area (where paddies are large). In addition to showing the flat nature of the entire area, fig. 91 shows the difficulties encountered when the rice "tops" the dikes as the growing season progresses.

129. Dimensions. The shape, size, and arrangement of dikes are illustrated in fig. 92. The cross-sectional dimensions cannot be obtained from the photos at the scale used. Variations in dike asymmetry were found to be so slight that they are not considered significant.

130. Relation to other factors. There are no significant relations to the other factors.

131. Regional distribution. This pattern can be expected to be widespread in the middle to lower portions of the Bangkok Plain where extreme flatness occurs.

Paddies with systematic parallel arrangement on flat terrain

132. Modern agricultural practices and the construction of large canals for the distribution of irrigation water have led, in some areas, to the development of large tracts of land in a manner that takes best advantage of these conditions. Paddies have been lengthened to take full advantage of tractor plowing and dikes are oriented for efficient water distribution. Parts of the Bangkok Plain exhibit this degree of alteration in the paddies, i.e., a change from the traditional paddy design (random shape and arrangement) to the systematic paddy design and arrangement (parallel dike/paddy plan). Two portions of the Bangkok Plain have been selected to illustrate systematic parallel paddy arrangement on flat terrain. The area covered by both illustrations is generally midway between Bangkok and Sara Buri, roughly 20 to 25 km east of Ayutthaya.

The area is crossed by the highway between Bangkok and Sara Buri.

133. Recognition on air photos.

a. Appearance. The dominating element of the pattern is the parallel organization of long rectangular paddies (figs. 93 and 94). The primary dike lineations are very long, straight, and parallel. Deviations in paddy size and shape occur only in natural depressions of former natural stream channels such as those extending across the upper portion of fig. 93. The area is broken only by canals, highways, and village platforms. Paddy/dike orientations are strongly related to the waterway orientations; i.e., primary dikes are perpendicular to the distributary channels, as shown in fig. 95. The arrangement of secondary dikes is not particularly consistent, suggesting that they may be related to the dike system which existed prior to modern practice.

b. Contributing elements. In addition to the shape, there are three main elements in the qualitative analysis of this feature. These are the extensive man-made distribution system for water, the strong parallelism of the primary dikes, and the flat terrain. All are obvious in the photos.

c. Genetic description. Since the pattern is the result of modern agricultural practice, it possibly represents a second generation paddy/dike system in the area. The former generation is represented by those paddies built in conformance with traditional practices of the farmer prior to the impact of more modern practices. The contrast between the two is clearly shown in all illustrations.

d. Factor estimate reliability. Recognition of the man-made canal complex and the parallel dike systems is 100 percent, except during periods of flood or just prior to harvest when the dike systems are not apparent.

134. Appearance on ground. When the rice stems are higher than the dikes, the area appears as one large field of rice on a very flat plain. At flood stage it appears as a huge lake.

135. Dimensions. As can be seen in fig. 93, the spacing of primary dikes varies. Because of the flatness of the terrain, error in measuring spacing would be less than that for spacing on hilly terrain. No field measurements of dikes were obtained in this area.

136. Relation to other factors. Because of the extensive irrigation system, there is a definite relation between the parallel paddy/dike system

and the hydrologic geometry factor. The soils of this flat area are alluvial clays.

137. Regional distribution. At present, this paddy arrangement is limited to the Bangkok Plain, but if irrigation and the trend toward improved agricultural methods continue to increase, similar conditions will develop on other flat areas in the Central Plain.

Boundary dikes in abandoned channels

138. Boundary dikes serve several useful purposes in wet rice agriculture. They may be used to exclude floodwaters from rong* agriculture, to limit areas subjected to tidewater, and to separate areas of minor topographic relief differences (abandoned channels). Boundary dikes related to abandoned channels represent a continuity of a prominent dike system that forms a boundary between two paddy systems without terracing. In extremely flat areas, boundary dikes of any appreciable size may present the chief mobility obstacle. The illustrations of this feature are from an area about 21 km southeast of Sara Buri (via roads No. 5 and 12).

139. Recognition on air photos.

a. Appearance. The channel area has been outlined by dashed lines in fig. 96. The actual boundary dikes can best be seen in the stereopair in fig. 97. As the name implies, boundary dikes form a definite continuous border. The continuity is broken in a few places, possibly where a slight slope occurs and the transition (or the boundary condition) spans two paddies. The dominating element is continuity of a prominent dike system that forms a boundary between two paddy systems without terracing.

b. Contributing elements. In the example chosen, recognition of a boundary dike is closely associated with the ability to recognize and bound a former channel. The most significant associated feature is the striking contrast between paddies of the channel and paddies of the adjacent areas, in terms of shape and arrangement. There are two patterns; one of large rectangular paddies (found in the old channel--irregular for curved portions), and one of smaller, more random shaped paddies of the adjacent areas.

c. Genetic description. Boundary dikes represent the attempt to exercise more efficient control of water in two adjacent

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* Rong--a raised soil ridge on which vegetables are planted.

areas. In this instance the controlling factor is the presence of a very shallow former stream channel.

d. Factor estimate reliability. Reliability for prediction of presence of boundary dikes similar to the ones in figs. 96 and 97 might be as high as 90 percent during most of the year. However, during periods of inundation and during the maturity stage of the rice, prediction reliability would be much less. Quantitative data concerning the dike sections cannot be obtained from photos of the scales used.

140. Appearance on ground. Recognition of boundary dikes such as those in fig. 96 from the ground is more subtle than from the air, particularly during the middle to late rice growth period. In areas of very slight topographic differences, the boundary dikes may be the same height as the dikes on the adjacent area, in which case a slight degree of asymmetry occurs. With increasing difference in elevation between the two areas, the degree of asymmetry increases. For very low elevation differences (less than 3 to 4 in.), the asymmetry cannot be seen on the ground very readily, particularly when water is in the fields or during the growing season. As the elevation difference approaches 6 to 8 in., it can be readily seen.

141. Dimensions. Field data were not obtained in this area.

142. Relation to other factors. The relation to other factors might be significant under certain conditions such as high water in the low area which would result in the boundary dike becoming a confining channel bank.

143. Regional distribution. This condition is believed to occur in areas representing the outward bounds (or projections) of an abandoned channel which is being absorbed into the continuity of the paddy plan of the surrounding area as that channel becomes shallower in depth. There are many such situations in the upper to middle zones of the Bangkok Plain.

Boundary dikes on tidal flats

144. In flat coastal areas, land is reclaimed for agricultural purposes by construction of large dikes, or levees, which limit the area inundated by tidewater. These dikes are much larger than ordinary rice

paddy dikes and can be major mobility obstacles. Where land has been reclaimed in increments, which is usually the case, a succession of such dikes may be encountered. Usually those which are closest to the sea water channels are the highest. The pattern selected (site SG-163) is about 16 km due south of Chanthaburi and about 8 km east of Amphoe Laem Sing.

145. Recognition on air photos.

a. Appearance. The most outstanding photo pattern element is the sharp difference in photo tone at the boundary: light for the developed area and dark for the active tidal flat. This change in photo tone is well illustrated in figs. 98 and 99. Some dark-toned areas, which represent the early stages of clearing may still contain some mangrove, nipa palm, and saltwater. Some of the dark-toned plots also are ponds for raising shrimp and therefore require periodic saltwater inundation, with the result that different vegetation can be expected in these areas. In some instances the sandy nature of some of the soils in such an area allows the high groundwater table to exert its influence on photo tone, particularly in the lower areas. However, even with cognizance of the exceptions, it is not difficult to distinguish between reclaimed and unreclaimed areas even at scales of 1:40,000.

Boundary dikes constructed early during reclamation are no longer at the edge of the active tidal flat; they are less obvious from small-scale photography. However, in many instances it is possible to identify particularly sharp dike lineations which appear to bound very large paddies. In some of these cases a secondary but less obvious dike system may be identified.

b. Contributing elements. The most significant contributing elements are related to topographic position and location with respect to the estuary and the lagoon. These elements are best obtained from critical study of photos covering a large area, including the region between the coast and the upland. Other contributing elements are linear boundaries, two or more primary dike systems, and sharpness of tone contrasts.

c. Genetic description. Boundary dikes of this type are the first to appear in an area being developed for rice agriculture in tidelands. Construction of the dikes is carried on concurrently with or prior to the removal of the brackish water vegetation, primarily nipa palm and mangrove; thus, they are related entirely to the reclamation of tidelands.

d. Factor estimate reliability. The reliability of identifying boundary dikes in connection with land reclamation is

approximately 80 to 90 percent at a photo scale of 1:40,000. At the same scale the reliability for identification of other boundary dikes is about 50 percent. Reliability estimates for other scales are not known.

146. Appearance on ground. Those dikes separating reclaimed from unreclaimed land are readily recognized on the ground (see ground stereopair in fig. 99). The recognition of former boundary dikes is no problem unless the height of growing rice masks the details being compared.

147. Dimensions. These dikes are often 2 to 4 ft or more in height and 4 to 12 ft in width. Possibly the best indicator of height likely to be encountered in an area where ground inspection is not possible is the tide range for that particular portion of coastline.

148. Relation to other factors. Soil conditions are pertinent to the use of boundary dikes because of the desire to minimize migration of saltwater through a dike during high tide. Soils in the study area are clays. Boundary dikes are of significance from a vegetation standpoint since they form a landward boundary for nipa palm and mangrove in areas undergoing reclamation.

149. Regional distribution. This situation is likely to be found in flat coastal areas.

Mountain valleys

150. Roads into the mountain highlands follow the valleys which often provide the only reasonable means of access, no matter how much the route may vary in terms of grade and alignment. With the exception of the Central Plain, the Khorat Plateau, and the coastline around the Gulf of Siam, Thailand is mountainous. The mountains vary in mass and physical expression from small outliers projecting through adjacent lowlands to great land masses of considerable diversity in relief and character. Valleys which provide access to mountainous areas also vary considerably in terms of their physical configuration. In the example selected, the valley represents relatively easy access throughout most of its length but terminates abruptly with a vertical rise accompanied by a small waterfall. The study area, site SG-8, is located in a valley about 8 km southeast of Sara Buri on the road to Wat Phra Chai.

151. Recognition on air photos.

a. Appearance. The dominating features of this valley are steep sides, flat-bottomed floor, and a relatively straight alignment throughout much of its length except in the upper portion (figs. 100 and 101). In the upper part, beyond the bend at site SG-8, the valley floor and sides change abruptly to a sharp V-shape between the bend and the waterfall area at photo site 3 in fig. 100.

b. Contributing elements. The diversity of relief is accompanied by changes in land use on the valley floor and by changes in natural vegetation on the valley sides. The steep slopes are mantled with dense timber and bamboo, while lower slopes (not cultivated) appear to be mantled with brush and grass. The stream occupying the valley floor is lined with trees. The valley floor is under cultivation (rice paddy and field crops such as corn) in the more favorable topographic areas.

c. Genetic description. The structural and lithological aspects of this area are not readily apparent on the photos used in this study. Detailed study of the photos of the entire mountain mass is needed before the genetic relations can be determined.

d. Factor estimate reliability. The situation illustrated in fig. 100 can be adequately described (qualitatively) with a reliability of about 75 percent if the description is confined to characteristics of the valley floor.

152. Appearance on ground. The characteristics of the valley floor are depicted in figs. 56, 57, 100, 102, and 103. Figs. 56 and 57 show paddy terracing in the midportion of the valley. The ground photo in fig. 100 shows the valley floor and side at location 1 on the air photo in fig. 100. Fig. 102 shows the broad valley floor just below the bend at location 2 in fig. 100. Fig. 103 shows the abrupt changes in valley floor at the waterfall area at location 3 in fig. 100.

153. Dimensions. Field data pertinent to slope and cross section were not obtained in this valley.

154. Relation to other factors. Along the thread of the valley (stream) the only relation during periods of low water would be to the vegetation. During periods of high water the stream would become a significant factor influencing mobility.

155. Regional distribution. A great diversity of landforms and rock types exists in the mountain masses of Thailand. Thus, the associated

valleys can be expected to exhibit diverse physical characteristics. In those parts of the study areas containing limestone (Pran Buri and Lop Buri), the valleys exhibit typical karst characteristics--discontinuity of the floor, steep side slopes, sinkholes, caves, etc. Where metamorphic rocks occur (Lop Buri, Chiang Mai, Chanthaburi), structural control dominates in establishing the grade, side slopes, and alignment.

Rolling karst terrain

156. Karst surfaces in Thailand include high massive limestone hills and mountains, sinkhole-studded plains, solution valleys, plains marked with large conical hills called pepinos, and plains marked with small but extremely jagged limestone pinnacles. One important karst area is the pepino/sinkhole region in the vicinity of Lop Buri. This area contains many outliers of limestone from the adjacent plateau to the east which rise conspicuously above the floor of the alluvial plain. In this region the thick limestone beds are steeply tilted and the pepino hills are closely aligned along the strike of the rock. These major, highly irregular land masses are flanked by broad limestone plains which merge imperceptibly with the alluvial soils of the Central Plain. Because of the extreme ruggedness of the massive pepino hills and the general inaccessibility to vehicle traffic, they have been eliminated from consideration in this study. Thus, this discussion is concerned with the minute surface features associated with the karst plain. The pattern location is adjacent to the mountain mass just southeast of Lop Buri. The area contains the following study sites: SG-26, -28, -73, and -124.

157. Recognition on air photos.

a. Appearance. Fig. 104 is a mosaic showing the relation between the rugged moutain mass (center portion) and the surrounding karst plains. There are three general karst conditions illustrated in this discussion. The area covered by fig. 105 is a gently rolling-to-flat plain marked by small island-like limestone outcrops in what appears to be an old solution valley. Sinkholes are notably absent in this photo. The more rolling portions appear to be under cultivation for field crops while the flat areas are in paddy. The limestone outcrops stand out sharply against the surroundings because of the contrast in land-use pattern. The area covered in fig. 106 is composed of highly irregular, minute hills, sinkholes, pinnacles,

and channels, all of which vary considerably in size and arrangement. Some of the sinkholes contain water and exist as ponds, some appear as brush- or grass-filled swamps, and some are connected and form a somewhat organized channel. Those which do not contain water appear to support rice cultivation, as evidenced by the paddies. The irregularly shaped terrain occupying most of the area, exclusive of the sinkholes, appears to be under cultivation (field crops) or in the process of being cleared. Many trees are scattered throughout the higher portions of the sinkhole plain. The area covered by fig. 107 is a sinkhole-studded plain which includes such features as flat surfaces, sharp-peaked, isolated, small hills, clusters of small hills, and small rock pinnacles. Notably lacking are erosive forms relative to surface runoff. Land use in this area appears to be grazing, field crops, some fruits, and an extractive industry (removal of rock for cement).

b. Contributing elements. In each of the air photos used, some portion of the adjacent upland is shown which lends support to the comments made regarding the physical and geological aspects of the area. The indirect indicators important to pattern identity are lack of surface drainage system and sharp contrast in land use between low areas (sinkholes and channels) and higher, more rolling areas. The brush is too dense to permit direct viewing of the minute aspects of the landscape; therefore, indirect methods must be used to infer its character. In croplands the surface can be seen easily and an appreciation of minute slope changes and presence of obstacles (dikes) can be obtained.

c. Genetic description. The air-photo patterns are related to processes of formation of karst features in a limestone region in a humid environment. The massive nearby hills (low mountains) exhibit the classical karst features found in other limestone regions in a similar environment. When viewed stereoscopically, the high terrain is marked with very large sinkhole areas, no surface drainage systems, steep-sided vertical forms, and a highly irregular surface forming the summit. In several places the dip and strike of the rock are clearly evident. The evidence of solutioning in developing the lower lying plains and hills which flank the major rock mass lies in the same general features being present, but on a much reduced scale.

d. Factor estimate reliability. It is not possible to give an expression of the reliability of quantitative aspects of the terrain from the scales used. However, there is ample evidence as to the type and origin of the material composing the landscape. This, when properly examined and applied, should result in 75 to 90 percent accurate description.

158. Appearance on ground. The examples shown in figs. 108-111 clearly illustrate the ground perspective of this pattern. The view in fig. 108 is representative of paddy land use in the broad flat areas of major solution channels in the plain. The soils are black in this area. Fig. 109 represents the sharp contrast between paddy land use in a sinkhole and diversified land use of the surrounding area (fruit, bamboo, corn). Fig. 110 shows the rolling topography flanking the major mountain mass at SG-26. Fig. 111 clearly illustrates the problem of vegetation obscuration and the possibility of contact with the pinnacles.

159. Dimensions. Field observations indicate low topographic relief of the karst plains on the order of 5 to perhaps 15 ft between highs and adjacent lows in perhaps 200- to 500-ft distance. The only sharp breaks in slope occur along the walls of the solution channels and the sides of some of the sinkholes. However, the step differences are on the order of 2 to 5 ft. The most serious minute topographic differences are those associated with the limestone pinnacles and the areas of shallow soil on exposed rock (fig. 111).

160. Relation to other factors. Soils derived from weathering of limestone in this area have been mapped by Pendleton[4] as Lop Buri clay and are classed as CH. There are no hydrologic features in the area other than the sinkholes. Most of the area is under cultivation with a small portion in the process of being cleared. As indicated, vegetation includes rice in flat low areas, field crops and fruit in higher areas, and dense tree stands along the borders of some of the channels.

161. Regional distribution. Extensive karst features occur in the peninsula along the border between Burma and Thailand, in the Hat Yai area, along the coast at Pran Buri, inland at Chanthaburi, and in the Lop Buri area.

Termite mounds

162. In many areas the landscape is dotted with soil mounds (generally attributed to termites). Because of their size these mounds must be included as mobility obstacles. Rarely, if ever, do they occur close enough together to present a vehicle barrier. Their mobility significance lies in the degree to which it is necessary for a route through them to

deviate from a straight line. It is common practice for farmers to take advantage of the mounds to minimize dike construction by incorporating as many as possible in the dike system. In some areas, almost every mound has one or more trees or other vegetation on it which stands out in strong contrast to the surrounding cultivated area. In other areas the mounds may be covered only with vegetation no more than a foot high. The region selected to illustrate the many variations in occurrence and characteristics of mounds lies north of an east-west line through Sara Buri. Sample sites at which observations were made regarding mounds are indicated in fig. 112.

163. Recognition on air photos.

a. Appearance. In rice paddy areas, termite mounds occupied by trees appear as randomly distributed dark spots with various degrees of concentration, and they may be easily recognized during any season at scales down to at least 1:40,000. Tree-covered mounds can be seen in the mosaic in fig. 112, which is printed at a scale of about 1:60,000. (The trees merely suggest the presence of the mounds at this scale.)

Where trees (or brush) do not occur on the mounds their presence is less obvious, and the degree of recognition is season-dependent. They are probably least apparent during the period when rice is in the intermediate to advanced growth stage. Fig. 113 is a stereopair taken after the rice harvest in January 1965 in an area where nearly all mounds are without trees. The dark tones in some areas are a result of burning of the rice stubble after harvest. During this period, and at times when there is no tall grass or rice, termite mounds stand out in best contrast. The minimum useful scale at optimum conditions is probably around 1:40,000. Additional comparative photo coverage would be needed for any further, more definitive comments concerning appearance.

The accompanying illustrations adequately depict frequency of occurrence. Fig. 114 is a stereopair of an area which contains dense mounds (site SG-52) and sparse mounds (site SG-51). Fig. 115 is a large-scale stereopair of an area of high termite mound density. The conditions depicted in fig. 116 (site SG-19) and fig. 117 (site SG-47) are also associated with dense termite mounds. Sparse mounds are depicted in figs. 114 (site SG-51) and 118 (site SG-50); these are generally lower and wetter areas.

b. Contributing elements. The main photo pattern element is an abundance of speckled or spotty (depending on photo scale)

markings which dominate the pattern. Dark spots are tree-covered mounds. Minute spots without trees may stand out in sharp contrast to the background--either lighter or darker depending upon season.

c. Genetic description. There are some interesting associations which have been observed in the field and in the photographs regarding the distribution of the mounds with respect to soil, topographic position, and moisture. These are indicated in the various accompanying illustrations. For example, mounds in the area covered by fig. 112 occur on the higher and drier parts of the broad regional slope from the mountains lying to the north and the higher and drier parts of the natural levees associated with Mae Nam Pa Sak. The areas having fewer mounds are in depressed topographic position such as abandoned channels and along watercourses subject to flooding (site SG-50).

d. Factor estimate reliability. The inferred presence of termite mounds from the recognition of the dark speckled pattern in rice areas approaches 100 percent reliability, but no reliability factor can be stated with regard to the observance of all termite mounds in such an area, since some may be without trees. Under the best seasonal conditions, anything approaching 100 percent reliability for recognition of cleared mounds probably stops at a photo scale of 1:10,000, possibly a little smaller. With regard to measurements, good estimates of spacing can be made in proportion to photo scale. Given adequate, large-scale photos, photogrammetric determination of size and shape is possible for cleared mounds but not for tree-covered ones.

164. Appearance on ground. Several ground photos illustrate this pattern (figs. 119 and 120, and the ground photos in figs. 116, 117, and 118). In addition to these photos, reference is made to figs. 63, 64, 71, 74, and 81 for illustrations of other termite mounds. In areas of dense mound distribution, the ground view is that of a landscape dotted with "never ending" clumps of trees. Individual mounds may vary greatly in size and shape. Mounds which have been made part of a dike are less obvious than those which are isolated, and in both cases the vegetative cover may conceal the mound entirely. Those mounds which are barren or grass- or crop-covered can be seen with ease at all times except during late crop-growth stages.

165. Dimensions. Mounds vary considerably in size and shape.

In general, they are rounded in plan and present a conical or dome-like section. Heights vary from 2 to 7 ft while the often circular bases may vary from 4 to over 30 ft in diameter. In some areas the mounds are cut back by farmers in order to reclaim the soil and to increase the paddy area. This often results in vertical sides. Insufficient samples were obtained to permit establishing any base area/height/shape relations.

166. Relation to other factors. Other related mobility-factor families are soils and vegetation. Termite mounds are not normally found in low wet areas consisting primarily of heavy clay soil; but they seem to abound on slightly higher, free-draining and lighter textured soils of the levees and the broad slopes. Mounds were not found on coarse-grained or rocky soils. Regarding vegetation, the mounds often support the only trees in the broad, extensively cultivated areas (rice) except for the village compounds and watercourses.

167. Regional distribution. Mounds occur in the broad intermontane valleys (Chiang Mai area), the broad flat to gently rounded valleys and major gullies of the Khorat Plateau, and in all but the extremely wet and heavy clay areas of the Bangkok Plain. They do not occur on highly alkaline soils nor on areas likely to be inundated for long periods of time.

## PART IV: VEGETATION

168. Vegetation includes all properties of plants growing on land, in or on water, and on other plants. In this context, vegetation incorporates not only the physical attributes of plant growth (structure) but also such things as the natural relations among plants (taxonomy) and the screening effects of the gross physical properties of plants (visibility). It is obvious that not all of these properties are significant to ground vehicle mobility; therefore, only those vegetation factors which are known to affect the performance of vehicles operating cross-country are considered in this part of the report. Since the effects of vegetation on vehicle performance are mainly obstacle-imposing ones, it follows that stem size and spacing are the two most important factors influencing performance. Other factors, such as plant height and crown or clump diameter, while not greatly influencing performance, contribute to pattern and feature identification and are therefore included in the discussions. The principal sources of published information used in this portion of the report are references 4, 7, 10, and 11 in Literature Cited. In addition, an unpublished survey, Thailand Survey of Vegetation by Llewlyn Williams (5 March 1964), was obtained from the Agricultural Research Service, U. S. Department of Agriculture.

### Selection of Examples

169. The air-photo patterns of vegetation types represented in this catalog were selected on the basis of most frequent occurrence and greatest occupance. A total of 11 vegetation patterns are included for discussion, as follows:

- a. Rice savanna
- b. Rong agriculture
- c. Tall field crops
- d. Shrub savanna
- e. Village compound
- f. Rubber plantation

g. Semievergreen forest

h. Bamboo forest

i. Evergreen broadleaf forest

j. Mangrove swamp forest

k. Nipa palm swamp

## Data Collected

170. Data on the selected vegetation patterns are included in table 4. This summary table contains the original field site number, location, date of sample, average stem or clump spacing, average stem or clump diameter, average plant height, an index to air- and ground-photo illustrations, and any pertinent remarks.

## Description of Catalog Examples

### Rice savanna

171. Rice production is the single most important factor in the economy, and perhaps political stability, of Thailand. Much of the Bangkok Plain is in rice culture and more acreage is so destined as new irrigation projects are completed. New varieties and increased mechanization and fertilization are the keys to continued rice production in excess of local needs. Rice is here considered as a low field crop although it may be 6 ft tall at maturity. With the addition of scattered trees, it is structurally similar to tropical savannas maintained by fire in Africa or responding to soil conditions as in South America.

172. Recognition on air photos.

a. Appearance. Rice paddy pattern is probably the largest continuous photo pattern encountered. The tones vary only slightly from one paddy to the next, but the bunds and irrigation ditches portray a sharp frame around each (figs. 121 and 122). The tones are very light, particularly at maturity and after harvest. Darker paddies are usually fallow areas in short grass. Texture increases slightly as the rice grows taller, but remarkable granularity is apparent at small scales. Paddies are burned after harvest and are then completely black. Dark-toned scattered trees

blend with their shadows and stand out in sharp relief against the light-toned rice. These trees are frequently found on termite mounds at the corners of the paddies. At scales of 1:40,000 or 1:15,000 the woody growth on a single termite mound appears as a single crown.

b. Contributing elements. Although upland rice (dry culture) is grown in isolated areas, the majority of rice pattern is in large tract on flat topography or on level valley floors extending into the uplands. Trees distributed so as to form a savanna may define the limit of termite mounds as in Lop Buri, or they may be uncut trees left after partial clearing of new agricultural lands. In other areas trees are scattered throughout the paddy system independent of bunds or termite mounds. Such areas probably represent a true climatic savanna environment altered by man to irrigate rice.

c. Factor estimate reliability. At 1:40,000, spacing estimates are over 90 percent correct. Estimates of tree stem diameters between 6-12 in. are 50 percent correct; reliability of estimates of rice is at least 90 percent.

173. Appearance on ground. Rice areas appear as a flat, grassy plain with a network of raised bunds that are hardly noticeable from the ground after the rice is several feet tall. Except for the generally treeless Bangkok Plain, widely spaced trees or clumps of trees interrupt this grassy plain (fig. 123). These trees may be single stems without lower branches, or dense underbrush may surround one or more tree trunks (fig. 124). During the rainy season, rice areas may be covered with water. During fallow periods short grass grows on the paddies and is grazed by cattle and water buffalo.

174. Dimensions. Most rice savanna trees or clumps are more than 30 ft apart; spacing of rice is not significant. Stem diameter of trees is usually at least 4 in. and seldom more than 14 in.; diameter of rice is not significant.

175. Relation to other factors. Soils of paddy rice or "floating rice" areas are clays that are saturated part of the year and dry hard during the dry season; trees occur only on occasional rises. Fertility is replenished each year by sediment deposition during seasonal floods. Although the topography is flat or nearly so, rice bunds and irrigation structures are severe obstacles to vehicle mobility. These same bunds

and dikes are the primary routes of travel by foot and bicycle in the rainy season.

176. Regional distribution. Rice occupies 70 percent of the cultivated area of Thailand. Most of the acreage is in wet culture on the Central Plain, but substantial amounts of rice are grown throughout all lowlands and river valleys.

Rong agriculture

177. A great variety of garden vegetables are grown for local consumption. In the lowland rice regions these crops are grown on raised soil ridges, called rongs, to establish root aeration. Although these garden crops, per se, do not affect vehicle mobility, the associated soil ridges are significant obstacles.

178. Recognition on air photos.

a. Appearance. Distinct rows of constant width and as long as a rice paddy occur in groups (figs. 125 and 126). Various tones from very light to very dark are associated with different vegetables or soils on the rongs. At a 1:40,000 scale, rong areas appear mottled but distinct from rice areas (fig. 125). The linear texture and sharply varying tones are perhaps the most distinctive pattern elements at any scale.

b. Contributing elements. Rong agriculture is one means of vegetable production that accounts for a distinctive photo pattern. Rongs are built on flat topography in wet soils to achieve drainage for plants not otherwise adaptable to rice areas. They are therefore frequently associated with irrigation canals or ditches and are usually adjacent to village compounds or village markets. Rong areas are seldom extensive; where they are extensive they contain houses. The ditches between each rong may or may not contain water. In upland areas vegetables are grown in small plots within village compounds and are usually not distinguishable from the village pattern in small-scale photography.

c. Factor estimate reliability. At 1:40,000, based on recognition of rong agriculture, probability of estimated spacing is over 80 percent. Reliability of stem diameter estimate is over 90 percent.

179. Appearance on ground. Rong agriculture is practiced exclusively in lowland areas. The rongs average 3 to 4 ft in width, and perhaps 100 ft or more in length. Usually short, leafy vegetable or root crops are

planted, although banana or coconut palm are occasionally grown on rongs. The intervening ditches are several feet wide and 1 to 2 ft deep. An example of a typical rong area is shown in fig. 127.

180. Dimensions. Spacing of vegetable or root crops is not significant. Normally there are no tree stems over 6 in. in diameter; occasional coconut palm or fruit trees may reach 10 to 12 in. in diameter and are readily identified in the air photos; diameters of vegetable and root crops are not significant.

181. Relation to other factors. Rongs are restricted to flat topography. The soils are usually high in clay or organic materials and poorly drained. Irrigation ditches are frequently associated features. Village compounds are a constant associate.

182. Regional distribution. Rong agriculture is most extensive on the Bangkok Plain, particularly near Bangkok, but the pattern also occurs in coastal areas and on local saturated soils near villages throughout Thailand.

Tall field crops

183. Tall field crops such as corn, sugar cane, and cassava limit vehicle mobility primarily through reduction in visibility.

184. Recognition on air photos.

a. Appearance. Tall field crops (figs. 128-130) at maturity usually are uniformly light gray in tone with no texture at a scale of 1:40,000. At 1:15,000 and larger scales, row crops may show a slight striation. Rice paddies are lighter in tone, forest and shrub areas darker. The boundaries of field crop areas are sharp and geometrical. After harvest the photo pattern is governed by subsequent crops such as peanuts or castor beans or by the underlying soil type. Following planting, the pattern caused by soil becomes rapidly more diffuse.

b. Contributing elements. Field crop acreage has increased rapidly in the past decade. Lowland rice areas have been cultivated for years, but adjacent rolling uplands are being cleared for new farms (figs. 128 and 129) and these are primarily suitable for tall field crops such as corn (fig. 130). The increased use of tractors in such areas means larger fields and fewer trees. Irrigation or drainage ditches are not normally constructed for these crops. After several years of cultivation the fertility may be depleted below levels for economic production.

The cropland may then revert to shrub savanna and pasture, or it may be completely invaded by tall tropical grass of similar vegetation structure. These tall field crops along with tropical grass are structurally related at maturity, although they may differ agronomically. Young growth stages are of minor mobility significance.

c. Factor estimate reliability. At 1:40,000, based on recognition of upland field crop, probability of estimated spacing is over 80 percent. Reliability of stem diameter estimate is over 90 percent.

185. Appearance on ground. Most tall field crops are grown in rows and reach heights of 10 ft at maturity (figs. 131-135). Occasionally secondary crops which mature after corn may be planted between the rows. Wild tropical grass grows in tangled clumps which may be so intermingled with adjacent clumps as to be nearly impenetrable on foot (fig. 136). Such areas are not harvested, but may be burned in the dry season.

186. Dimensions. The rows average 24 in. apart; stems are closely spaced within the row. No stems are over 6 in. in diameter; diameter of most stems is less than 1 in.

187. Relation to other factors. Tall field crops require well-drained soils and are usually grown on gentle topography. Since the soils are usually residual, they may be deeply weathered. Irrigation and drainage are not usually required. Stream channels dissecting the terrain may contain water only in the wet season.

188. Regional distribution. Tall field crops occur extensively in the Khorat Plateau, in the Nakhon Sawan and Lop Buri areas, and to a lesser extent in the Chiang Mai, Chanthaburi, and Pran Buri areas. Thailand is now a major exporter of corn, so additional acreage of this crop may be expected in the near future at the expense of forests.

Shrub savanna

189. Shrub savannas (fig. 137) are variable in composition and structure. They may be brushy pastures, high or low shrubs on abandoned agricultural land, or thorn scrub on saline soils or laterites. In most cases they occupy land too poor for agriculture because of a soil limitation. They frequently indicate some degree of disturbance by man.

190. Recognition on air photos.

a. Appearance. A definite, fine granular texture is caused by discrete shrub crowns which may or may not contrast sharply with a background of grass or soil. Widely scattered trees appear as taller, larger crowns with a distinct shadow. At a 1:40,000 scale, shrub crowns are barely perceptible (fig. 138); at larger scales shrub crowns are uneven in shape, spacing, and height. Borders of the pattern may be abrupt in contact with cultivated lands, and they may also grade imperceptibly to scrub forest.

b. Contributing elements. Some shrub savannas are relatively stable; others are maintained by grazing. Still other areas are merely transitory between previous agricultural abuse and forest regeneration. Consequently, such a potpourri is not closely correlated with other specific terrain elements. It is distinct from cultivated patterns, although frequently adjacent to them. Frequent associations include saline soils of filled estuaries, xeric soils of sandy beach ridge zones, overgrazed and shallow soils, and cleared and eroded lateritic soils of low fertility. Shrub savannas are seldom found on rich alluvial soils.

c. Factor estimate reliability. At 1:40,000, this vegetation type will be identified only 50 percent of the time. Stem spacing, although frequently averaging over 12 ft, cannot be predicted at this scale. At a 1:15,000 scale, spacing can perhaps be established in 5-ft increments. Stem diameters can be predicted to be generally less than 6 in. on the basis of type recognition. Direct observation cannot be made, and shrub crown diameters are not reliable because of clumping.

191. Appearance on ground. Shrub savanna, either high or low, features scattered individual crowns of one or frequently many stems in a matrix of low grass or bare ground (figs. 139-141). Woody plants may be thorny, evergreen, or deciduous. Crowns composed of small leaves may be variously shaped but generally extend to the ground. When shrub crowns merge or tree crowns are frequent, the pattern is more properly thought of as scrub forest.

192. Dimensions. Stem clusters range from 10 to 50 ft apart. Closer spacings result in crown closure. Stem diameters seldom exceed 4 in.; clump diameters range from 1 to 45 ft. Ground measurements of some typical shrub savanna areas (sites VG-50, -54, and -79) are included in table 4.

193. Relation to other factors. Surface geometry in shrub savanna

is varied. The topography may be gentle to rough, and the microrelief can be smooth, rocky, or dissected by erosion. In general these areas are drier than the surrounding vegetation types and the soils tend to be rocky. Hydrologic features are either absent or randomly associated.

194. Regional distribution. Shrub savannas are found in all study areas throughout Thailand, although they are more abundant in foothill zones and in drier areas.

Village compound

195. The Thai in rural areas live as single families or in groups of families in a village compound. In the rice areas where land is at a premium and also subject to flooding, dwellings are usually congregated in groups on local rises in the landscape (fig. 142). The typical assortment of wild and planted fruit trees, palms, bamboos, and other food plants associated with these villages composes the photo pattern called village compound.

196. Recognition on air photos.

a. Appearance. Village compounds in rice areas such as the Bangkok Plain appear as dark-toned rectangles in a matrix of rice paddies (fig. 143). Small single-dwelling compounds are nearly square with trees outlining a hollow box configuration. Multiple-dwelling units have less geometric patterns and in fact appear elongated along khlongs, rivers, and roads.

b. Contributing elements. Village compounds are conspicuous in rice areas; they are not easily identified in areas of fruit orchards. Frequently garden crops, bananas, papaya, or rong agriculture is adjacent to village compounds.

c. Factor estimate reliability. Stem spacing is highly variable; at a scale of 1:40,000 estimates are limited to type identification. At scales of 1:15,000 or larger, estimates in increments of 4 ft will be reasonably accurate. Stem diameters can only be inferred from type identification.

197. Appearance on ground. Houses in village compounds are usually on stilts in a small area of bare ground surrounded by a rectangle of trees (figs. 144 and 145). A dense fence of bamboo or thorny shrubs may surround a compound to contain livestock. The tree crowns may be closed, obscuring the dwelling. Larger, multiple-unit compounds tend to parallel roads or line rivers and canals. Varying amounts of understory grow beneath such

taller trees as mango, papaya, and coconut palm in the compound.

198. Dimensions. Stem spacing is highly variable and cannot be estimated at scales smaller than 1:15,000. In general, stems over 6 in. are over 4 ft apart. Stem diameters vary up to 24 in. in older compounds.

199. Relation to other factors. Village compounds are associated with rural areas with intensive agriculture. They are usually positioned on topographic rises in lowland alluvial areas and at the base of slopes adjacent to rougher topography. When they are associated with conspicuous watercourses, these may be presumed to be permanent water features which form the principal transportation net.

200. Regional distribution. Village compounds are found throughout the nonforested portions of Thailand but are most evident on the Bangkok Plain.

Rubber plantation

201. Acreage in rubber has increased since World War II to 662,000 acres (1 percent of the country) in 1960. The majority of the production is exported as raw rubber. The small farmer is being encouraged by the Government to plant trees, and accordingly about 80 percent of the rubber groves are 20 acres or less.

202. Recognition on air photos.

a. Appearance. Rubber grove patterns are uniform medium-gray tones, very slightly striated at 1:40,000, with sharp borders coinciding with field or property boundaries (fig. 146). All trees are the same height; individual crowns are not distinguishable. Pattern texture is soft, diffuse granular at a 1:40,000 scale. The canopy may be interrupted by rectangular clearings of lighter tones representing crops or young rubber groves. Adjacent forest is darker in tone and less uniform than rubber plantations.

b. Contributing elements. Rubber plantations are associated with deep, well-drained soils (fig. 147) because of their well developed tap root system (fig. 148). Therefore, rubber occurs on sloping or rolling topography above rice paddy land near roads. Plantations in Chanthaburi are not drained or irrigated.

Rubber plantations are structurally representative of several types of tree plantings including coconut groves and teak reforestation. Some of the larger fruit tree orchards are also planted in rows or grids but do not achieve

canopy closure; that is, individual trees remain distinct. Village areas are darker in tone and form a more heterogeneous pattern.

c. Factor estimate reliability. At 1:40,000, there is a good estimate of stem spacing from striations and feature recognition (probably over 75 percent). There is no estimate of understory conditions. Stem diameter estimate is 90 percent that trees are less than 12 in. and 80 percent that trees are over 4 in. if the canopy is closed.

203. Appearance on ground. Rubber trees (Hevea braziliensis) are planted in rows in deep, well-drained soils. The rows may be aligned in two directions but are more commonly aligned in only one. Mature trees seldom exceed 1 ft in diameter, and they are less than 50 ft tall with clear boles up to 20 ft above the ground (fig. 149). The larger commercial groves are devoid of a woody understory. On smaller private holdings, coffee (Coffea arabica) or pineapple may be planted between the rows, or successional woody brush may occur as a dense undergrowth over 6 ft tall (fig. 150). In such cases trails wind from tree to tree along each row of rubber trees. After 20 years, older groves may be cleared and replanted at 100 to 250 trees per acre (fig. 151). Tropical grass or upland crops may be grown among the young trees until the crowns have formed a closed canopy. Frequently, the felled trees are windrowed along a row of stumps and left to rot between the new rows. This practice is preferable to burning because the nutrients are recycled slowly as the new trees develop. Trees are tapped at about six years of age (fig. 152).

204. Dimensions. Spacing includes regularly spaced rows or grids approaching 17 by 17 ft or 10 by 25 ft. Stem diameters average 8 to 10 in. Structural data on selected sites (VG-80, -96, and -97) are given in table 4.

205. Relation to other factors. Rubber plantations are structurally similar to teak (Tectona grandis) plantations in northern Thailand. Coconut is also planted in rows of comparable spacing and diameter but on a smaller acreage. The larger fruit trees, such as durian in the Chanthaburi study area, are comparable in spacing and diameter but, unlike rubber, teak, and coconut, durian retains branches nearly to the ground. Village compounds are variously related to the orchard plantations but have a great

variety of heterogeneous species and appear as hollow boxes from the air.

206. Regional distribution. Rubber is grown chiefly in the southern part of the peninsula in the Hat Yai area and in the southeastern coastal zone in the Chanthaburi study area.

Semievergreen forest

207. About 60 percent of Thailand is covered with some type of forest. Semievergreen forests do not occur in southern Thailand but are extensive in the northern and eastern provinces, occupying 70 percent of forested land. These forests, which include teak, are an important commercial asset.

208. Recognition on air photos.

a. Appearance. Semievergreen forest patterns are granular in texture because of the various tree crown heights (see figs. 153-156). Tone varies from dark to medium gray; deciduous crowns are light-toned. At a 1:40,000 scale, a mottled pattern is evident that is partially a function of sun angle on the different slopes. Extreme mottling associated with a geometric tone contrast suggests clearings caused by shifting cultivation. The regeneration stages will appear short and light in tone. At 1:40,000, scrub forest may appear less granular as a result of small crowns and more uniform heights. Degenerate forests that are partially cut have large trees scattered throughout the scrub and therefore appear more granular.

b. Contributing elements. Rough topography is the primary habitat of semievergreen forests. Slopes may be rolling to precipitous. Road nets are restricted to a few main arteries. New agriculture is steadily encroaching on upland areas. Permanent streams and rivers dissect the forest regions.

c. Factor estimate reliability. At 1:40,000, spacing estimates can be made in 10-ft increments. Average stem diameters can be estimated in 5-in. increments.

209. Appearance on ground. The semievergreen forests are highly variable in spacing and diameter. To some degree the variation of these parameters can be judged from crown diameters and other criteria of apparent disturbance. An understory is commonly composed of smaller species and regenerating dominants. The ground surface is relatively bare in undisturbed stands. Even in planted teak plantations, very few understory plants grow on the forest floor. Epiphytes and lianas are smaller

and less frequent than in moist evergreen forests. Fifty feet is an average canopy height for much of this forest. Many of the dominants belong to the family Dipterocarpaceae. The extreme variability of the characteristics of individual stands is illustrated in figs. 157-160.

210. Dimensions. Stem spacing is variable. Mature stands may have average spacings of 20 ft, secondary scrub forest may have spacings of 10 ft for stems over 1 in. Stem diameters may be 20 in. or more in old stands but commonly average nearer 6 in. Table 4 includes field measurements of sites VG-2 and -34 in the Lop Buri area. Measurements were not made at site VG-1.

211. Relation to other factors. Little correlation with soils is expected although most are residual, usually with well-drained profiles. Large watercourses are permanent hydrologic features, while smaller channels may only contain water during rainy periods.

212. Regional distribution. Semievergreen forests are extensive at altitudes below 3000 ft in northern Thailand and in the eastern provinces. This includes portions of the Chiang Mai, Nakhon Sawan, Lop Buri, and Khon Kaen study areas.

Bamboo forest

213. Bamboo forests occupy extensive areas and may be one of the most significant vegetation obstacles to vehicle mobility.

214. Recognition on air photos.

a. Appearance. Areas of bamboo at a 1:40,000 scale are light gray in tone with a soft texture (figs. 161 and 162). Individual tree crowns are often included within the stand and standout as dark, well-defined tones against the bamboo matrix. At larger scales the clumps of bamboo may appear as rosettes of soft plumes.

b. Contributing elements. Bamboo invades fallow land and is therefore abundant in areas of shifting cultivation. Although bamboo is planted around village compounds and grows along streams, it is most extensive on upland slopes. Soils are variable although commonly well drained and residual in origin.

c. Factor estimate reliability. Identification of bamboo forest implies clumping, and distance between clumps cannot be determined at a 1:40,000 scale. Pure bamboo can be identified, but with increasing amounts of trees the

pattern is easily confused with scrub forest with which bamboo gradually merges. Stem diameter is inferred to be less than 4 in.; stem clump diameter is significant but cannot be inferred.

215. Appearance on ground. Bamboo forests are dense stands, often of a single species such as *Thyrsostachys siamensis*, *Oxythenanthera albociliata*, *Bambusa arundinacea*, and *Dendrocalamus membranaceus*. Some species are thorny; others are not (fig. 163). Very little grows beneath dense stands. Bamboo plants bloom when they are 20 to 30 years old and then die; if a stand consists of equal age plants, the whole stand dies after flowering. Bamboo clumps are 12 to 35 ft tall (fig. 164). It is frequently possible to pass easily between the clumps on foot (fig. 165), but some thorny stands are virtually impenetrable (fig. 166).

216. Dimensions. Bamboo stems grow in tight clumps 10 to 12 ft apart or less. Since stems and crowns diverge from the base, the crowns usually interlock about 3 ft above ground. Clump diameter is 2 to 3.5 ft in the stands measured. Selected ground measurements of two different stands (sites VG-55 and -60) are presented in table 4. Measurements were not made at site VG-13.

217. Relation to other factors. Dry bamboo stands are frequently associated with slopes of pepino hills. Bamboo is also common along natural streams throughout Thailand. No consistent soil relation or surface geometry correlations were established.

218. Regional distribution. Bamboo forests occur in the drier portions of Thailand and consequently are of greatest importance in the eastern, central, and northern provinces. Bamboo growth is an important vehicle consideration despite its small stem diameter because it is so universal in the understory of scrub and secondary forests.

## Evergreen broadleaf forest

219. Undisturbed evergreen forests in high rainfall zones have comparatively little undergrowth. There is little undisturbed forest of this type remaining, especially near road nets or cart trails. Perhaps one-third of the forests of Thailand can be considered as evergreen broadleaf forests.

220. Recognition on air photos.

a. Appearance. This forest has a mottled pattern (fig. 167) due to (1) variations in print tone caused by reflectance differences in the many species composing it, (2) shadows of the uneven canopy, and (3) the rugged topography to which good forests are now generally restricted. Tone is lighter than mangrove and generally darker than cropland. Coarse texture is conveyed by large and small crown diameters and varying canopy heights. Variations in texture are frequently due to shifting agriculture and partial clearing (fig. 168). Emergent crowns are conspicuous when viewed stereoscopically (fig. 169).

b. Contributing elements. Most heavily forested areas are restricted to steep rugged topography. Extensive areas of forest are associated with poor or nonexistent transportation nets. Soils are usually residual or colluvial and well drained. Stream channels contain permanent water flow and are also subject to torrential flows following rainy periods. Evergreen broadleaf forests include rain forest and wet monsoon forest types. Structurally these communities are very complex and taxonomically diverse.

c. Factor estimate reliability. Spacing is inferred from type identification and estimate of stand maturity. Crown spacing can be measured on a 1:5000 scale with adjustments made for obscured understory stems. Diameter is inferred from apparent crown diameter.

221. Appearance on ground. On the edges of forests along streams, roads, and clearings, a dense canopy, usually entangled with lianas, extends from the tall trees down through the smaller trees, dense shrub, palm and bamboo zone underneath to the ground (figs. 170-172). Visibility in this ecotone is severely limited even in cut-over stands. Horizontal visibility within a forest stand improves with increasing age of the stand. The trees are not uniform in age, height, diameter, or species. Large trees with emergent crowns may be up to 3 ft in diameter; however, a greater diameter at ground level may be occupied by flaring buttresses. Numerous lianas and epiphytes are present; few thorny species are encountered.

222. Dimensions. Spacing is variable depending on stand maturity; older, partially disturbed stands approach 9 ft mean spacing for tree stems over 1 in. and 10 to 12 ft for stems over 6 in. Stem diameters range up to 3 ft, but average only 8 in. in the stands sampled. Detailed

structural data on a typical site (VG-99) are given in table 4.

223. Relation to other factors. For mobility purposes, the greater the disturbance by man up to the point of clearing and cultivation, the less the visibility. Limited cutting for timber tends to encourage regeneration and thus decreases spacing values. Rough and steep surface geometry may be a greater vehicle limitation than forest vegetation itself.

224. Regional distribution. Rain forests formerly occupied much of the peninsula and mountain ranges along the Burmese frontier and coastal regions in southeastern Thailand. These are being encroached upon by agricultural land used for rubber and upland crops. Substantial areas of this type of forest remain in the mountains of the Chanthaburi and Pran Buri study areas.

Mangrove swamp forest

225. Mangrove swamps are pantropical forests associated with the intertidal zone and adjacent areas having saline groundwater. In fact, mangroves are reported to dominate 75 percent of the world's coastlines between $25^{o}$N and $25^{o}$S latitude. The principal species in Thailand are *Rhizophora mucronata* and *R. conjugata*.

226. Recognition on air photos.

a. Appearance. Mangrove trees appear uniformly dark in tone with little texture (figs. 173 and 174). The canopy is continuous and of uniform height up to 35 ft. Mangrove forests are confined to muddy coastal fringes and brackish streams and estuaries. The water-forest border may be lobate as areas of mangrove invade to greater water depths.

b. Contributing elements. Mangrove is indicative of brackish water subject to tidal fluctuations and of fine-grained alluvial soils, probably deposited in a saline environment. It may occur adjacent to nipa palm along streams. Adjacent water depths depend on the tide and may be up to 6 ft. Mangrove swamp is a type of coastal vegetation. There are other kinds of swamp forests in Thailand, but none have the profusion of prop roots characteristic of natural mangrove.

c. Factor estimate reliability. Spacing is inferred from identification of mangrove type. Type identification probability is over 85 percent. Stem diameter probably can be inferred from height class only at large scales.

227. Appearance on ground. Typically the dense profusion of intertwining adventitious prop roots are exposed at low tide (figs. 175 and 176) and inundated at high tide (fig. 177). New aerial stems may arise from these roots. The trees are planted and cut frequently for charcoaling (fig. 178) and, as a consequence, the forest is often reduced to a random sequence of regeneration stages interlaced with water channels. Stems seldom exceed 6 in. in diameter or 30 ft in height and are not dense unless cultivated.

228. Dimensions. Spacing of stems is less than 3 ft, although prop roots form a network. Stem diameter is less than 6 in.

229. Relation to other factors. Undisturbed mangrove swamps are penetrable only along natural watercourses. In disturbed stands mobility is proportional to the number of boat channels created. Soils are predominantly clays. Typically the adjacent hydrologic feature will be 2 to 5 ft deep at high tide.

230. Regional distribution. Mangrove swamp forests are extensive along the coast and bordering brackish streams within the lower reaches influenced by tidal fluctuations in the eastern part of the Chanthaburi study area. Although some mangrove species can be cultivated with freshwater, natural assemblages do not compete successfully beyond the saline environment. Extensive areas also occur on streams draining into the lagoon (Thale Sap Songkhla) and along the southeastern shore of the lagoon in the Hat Yai area. Mangrove swamps are nearly continuous on the western coast bordering the Andaman Sea.

Nipa palm swamp

231. Nipa palm (*Nipa fruticans*) swamps are distributed at sea level in tropical East Asia and the South Pacific in the intertidal zone, particularly bordering tidal streams. Nipa palm is less salt-tolerant than mangrove.

232. Recognition on air photos.

a. Appearance. Nipa palm is recognizable on vertical and oblique aerial photos at a 1:20,000 scale by its feathery appearance, medium tone, uniform height, and location along brackish streams. The tone contrasts sharply with dark mangrove trees, although at 1:40,000 it may be

indistinguishable from rice fields except by the absence of bunds and geometrical borders. Figs. 179 and 180 illustrate the appearance of nipa palm areas at a scale of about 1:40,000.

b. Contributing elements. Nipa areas occur inland or upstream from mangrove forests. They may border canals for considerable distances into cultivated areas. The nipa is found mixed with mangrove, particularly where mangrove has been extensively cut. In all cases it grows in saturated soils along coasts seldom far from brackish water.

c. Factor estimate reliability. At 1:40,000, nipa swamp can be identified as a type with perhaps 70 percent probability. The identification approaches 100 percent at scales larger than 1:20,000. Lateral spacing is essentially similar for all stands observed and is, therefore, a function of vegetation type recognition. Stems (leaf midrib) do not exceed 2 in. in diameter, although clustering is significant.

233. Appearance on ground. Nipa palm has no stem. Long upright leaves 10 to 15 ft high form a uniform stand (fig. 181). These leaves are clumped and so entangled that they do not present a rosette configuration from the air. Very few other plants are found associated with them. The fruits are eaten and the leaves are cut for thatching. Nipa swamps may occur as thin borders along a stream or as extensive areas, usually inland from mangrove.

234. Dimensions. Clumps of leaves are less than 3 ft apart. There is no woody stem; however, clustering index and associated soil parameters make this a significant mobility type.

235. Relation to other factors. Nipa is always associated with a hydrologic feature which is influenced by tidal fluctuations. Water depth adjacent to nipa may be over 7 ft; soils are clays. The topography is flat and the soil is alluvial in origin. Only tall tropical grass and grass crops such as sugar cane, corn, or cassava are structurally related, and they occur on well-drained soils.

236. Regional distribution. Nipa palm is distributed at sea level throughout the tropics of Southeast Asia in the intertidal zone, particularly bordering brackish streams. It may be inland or upstream from mangrove. Nipa is extensive in the Chanthaburi study area and presumably common in the Pran Buri and Hat Yai areas.

## PART V: HYDROLOGIC GEOMETRY

237. Hydrologic geometry is concerned with the shape, size, and distribution of water bodies. Since these characteristics vary markedly with time, the temporal variance is also a matter of concern. There are dynamic considerations as well, of which current velocity is an example; however, no attempt was made to include dynamic considerations in the study because of the impossibility of interpreting them from most aerial photography. Although excessive water depth will inhibit the passage of nonswimming vehicles, it is the approach and exit configurations (where vehicles enter or leave the water) that appear to be the most critical considerations. Thus, as in the case of surface geometry, cross-sectional profiles of the channel, extending at least to the tops of its immediate banks, are used as the most satisfactory method of permitting the recovery of the necessary terrain parameters. These parameters are: contact approach angle, step height, position of step base, and water depth. The principal source of published information used in this portion of the study is reference 7 in Literature Cited. In addition, unpublished information entitled Technical Record of the Design of the Greater Chao Phraya Project of Thailand by August L. Ahlf (1 August 1963) was obtained from the U. S. Bureau of Reclamation, Denver, Colorado.

### Selection of Examples

238. The water bodies selected for pattern analysis in this study are the most commonly occurring hydrologic feature in Thailand exclusive of large streams. The selected features are discussed in the order of their occurrence starting from the coastal areas and extending across the lowland plains, the alluvial aprons, and into the mountains. A total of 10 features have been included as examples. These are:

a. Coastal features

b. Distributary streams

c. Meander scars and oxbow lakes

d. Large canals

e. Small canals and irrigation ditches

f. Sinkhole ponds

g. Small streams

h. Borrow pits

i. Swamps

j. Mountain streams

## Data Collected

239. A summary of hydrologic geometry data included in this catalog is given in table 5. This table includes original field site numbers, location, date of sample, and references to cross-sectional profile and photo illustrations. The data were collected in the Nakhon Sawan, Chiang Mai, Lop Buri, Khon Kaen, and Chanthaburi areas by two separate field teams.

## Description of Catalog Examples

### Coastal features

240. This group includes hydrologic geometry features, such as estuaries, tidal streams and flats, flooded fields, and water-filled swales between beach ridges, which are related to coastal areas.

241. Recognition on air photos.

a. Appearance. Estuaries and tidal streams display an irregular curved configuration--often serpentine in appearance (figs. 182-184). These irregularly shaped patterns are fringed on either side by wide dark-toned areas of vegetation which further outline their configuration. Flooded fields are indicated by small dark-toned square or rectangular patterns lying just outside the irregular dark-toned fringes which border the serpentine-like tidal streams (see figs. 182 and 185). Water-filled swales between beach ridges (see location 3 in fig. 183) appear as narrow areas of dark gray tones bounded on either side by parallel ridges of a very light tone.

b. Contributing elements. Water on the land (flooded fields, tidal flats, or within areas covered by dark-toned

vegetation which border many of the tidal streams) can best be seen where the photography contains an area of solar specular reflection (such as the tidal stream on the lower right edge of fig. 182). The extremely light tone of the water is in strong contrast with the bordering dark vegetation under this condition.

c. Genetic description. The coastal hydrologic geometry features in fig. 182 reflect the processes of deposition of sediments by large rivers which empty into the sea in a location where the stream current is affected by daily oceanic tides. Ocean waves are responsible for beach deposits along the seaward edge of such a lowland area. Daily tide fluctuations cause the main stream to periodically flood, submerging much of the lowland behind the beach ridges. These fluctuations are accompanied by deposition. Current directions of many of the small channels in these lowlands are reversed twice daily as the tides ebb and flow. Vegetation tolerant of brackish conditions, such as nipa palm and mangrove, thrives on this periodically submerged land. Much of the dark-toned pattern which fringes the tidal streams in fig. 182 is related to this type of vegetation. Man attempts to utilize and cultivate portions of old tidal flats as is evidenced by the rice field pattern observed in the lowland area in fig. 182.

d. Factor estimate reliability. In fig. 182, portions of the estuary of a large river are quite dark in tone, an indication of relative water depth. Other ground mobility parameters cannot be reliably determined at the scales used in this study.

242. Appearance on ground. Surface photos of tidal stream features are shown in figs. 186-188. Fig. 189 is an aerial oblique of a fish trap in a river estuary. The fish trap is at water level in fig. 190. The presence of fish traps is not a very reliable indicator of water depth because, while many traps of this type are used in waters shallower than 5 ft, others have been noted in waters as deep as 15 ft. Fig. 191 shows a water-filled swale between beach ridges. Water is kept in this swale for raising fish and shrimp. A series of man-made fish- and shrimp-raising ponds constructed near the coast is pictured in fig. 192.

243. Dimensions. Some of the horizontal dimensions of these features can be judged by comparison with the scale bars in figs. 182

and 183. A cross section of the shrimp ponds pictured in fig. 192 is presented in fig. 193.

244. Relation to other factors. For the most part, soils in the coastal tidal flat areas consist of fine-grained materials (silts and clays). Sands are associated with the beach ridges which often are the high areas between water-filled swales. Beach ridges, road embankments, and rice paddy dikes are about the only surface geometry features present in these lowland areas. Dense nipa palm and mangrove abound in these coastal tideland areas. Most of the stream courses are thickly fringed by this type of vegetation.

245. Regional distribution. These patterns are to be found along most low coastal areas of Thailand where large rivers enter the ocean.

Distributary streams

246. This feature includes the maze of branching and rejoining stream channels which flow across very flat terrain characteristic of major river deltas.

247. Recognition on air photos.

a. Appearance. This feature is marked by a very irregular pattern of uniformly light-toned, interconnected, crooked lines of varying widths (water-filled stream channels). This pattern is many miles in areal extent (figs. 194-196).

b. Contributing elements. The sharp contrast between the uniform gray tone of water and the somewhat irregular tones of the adjacent land background is an important aid in the delineation of the stream system. Often the streams are outlined by the high density of cultural activity along their banks. Under stereoscopic viewing, they can be identified as water-filled linear or irregular depressions on a landscape showing virtually no other type of natural relief except possibly some natural levees.

c. Genetic description. Patterns of distributaries are associated with streams flowing across deltaic terrain. As a stream's velocity decreases upon reaching such an area, it begins filling its channel by dropping much of its load and at times is forced to create new channels to by-pass blocked zones. These new channels (distributaries) often meander extensively across the very flat terrain and either find their way back to the original channel some distance downstream or join some entirely

different tributary channel system. Daily tidal action contributes to the creation of this type of pattern through the influence of high tides which retard the discharge of streams into the sea, reducing the current in the streams and causing them to drop more of their load.

d. Factor estimate reliability. Small-scale photography (1:40,000) provides a satisfactory image size for easy determination of a distributary complex. Very large scale photography (1:1000 or 1:500) would be needed to evaluate detailed ground mobility parameters.

248. Appearance on ground. Because of the great magnitude of the feature, only a small portion of it is visible from the ground. This small portion cannot be recognized as belonging to a distributary system because it cannot be related to the overall pattern.

249. Dimensions. By its very nature a distributary system implies relatively broad yet shallow stream courses. The exception is the main trunk of the stream system which tends to be deeper than its distributaries throughout the extent of the pattern. These main channels can often be identified by the cultural activity which has developed along their banks as a result of the permanency of the feature relative to its more temporary distributaries. This relation can be seen in fig. 195. Hydrologic geometry cross-section data are not available for features of this pattern.

250. Relation to other factors. Fine sands, silts, and clays are associated with this feature. In areas of rice cultivation, tree-like vegetation is usually limited to the cultural areas bounding main channels. A very flat topography, broken only by natural levees and cultural activities, characterizes this feature.

251. Regional distribution. This feature predominates in the lower Bangkok Plain and in the low coastal areas where large streams empty into the sea near Chanthaburi.

Meander scars and oxbow lakes

252. These features are associated with rivers flowing across broad alluvial areas of low regional slope inland from the sea or ocean.

253. Recognition on air photos.

a. Appearance. Meander scars appear as patterns of

smoothly curved, arcuate bands inscribed in landscapes of very low relief in the vicinity of meandering streams (figs. 197 and 198). Meander scars are shallow topographic lows separated from one another by low intervening ridges. Seasonal water occurs in these topographic lows (fig. 199). Oxbow lakes are also arcuate in shape (figs. 197 and 199); however, they usually are wider than meander scars. They appear like river bends no longer connected with the main river. The cross sections of both features tend to be asymmetric, with the outside of the curved portion having steeper banks than the inside. The deepest portions of these "channels" tend to lie closer to the outside curved banks. Meander scars may not contain water during the entire year, whereas oxbow lakes usually contain water throughout the year and are deeper features than meander scars since they are essentially water-filled portions of river channels.

b. Contributing elements. Water in these features tends to enhance their arcuate patterns. Meander scars tend to be light in tone in relation to the intervening ridges. Dense vegetation creates dark tones which outline the meander scars, particularly when they occur on the low ridges between depressions.

c. Genetic description. Meander scars were formerly portions of stream channels and result from adjustments in channel alignments. As a meander becomes large enough to loop back on itself, the looped portion of the stream is cut off from the main channel, and a water-filled loop of former stream channel is left. This loop is termed an oxbow lake. These lakes tend to become filled through the gradual accumulation of vegetation.

d. Factor estimate reliability. Identification of these features on 1:20,000- or 1:40,000-scale photography is highly reliable. Reliability of any estimate of the terrain factors pertinent to ground mobility from air photos at a scale of 1:40,000 is practically nil. With larger scale photography, perhaps at 1:1000, or 1:500, photogrammetric techniques may be applicable and direct measurement of mobility parameters might be made.

254. Appearance on ground. The oxbow lakes examined in the Lop Buri area are rapidly being filled with vegetation (see figs. 200-203). Oxbow lakes without an accumulation of vegetation, such as those on the air photos in figs. 197 and 198, can be expected to be deeper than those vegetation-filled ones examined in the Lop Buri area.

255. Dimensions. Fig. 204 contains cross sections of two oxbow

lakes in the Lop Buri area. Oxbow lakes without vegetation accumulation, such as appear in Nakhon Sawan, were not examined by any hydrologic geometry teams in Thailand. However, they can be expected to be deeper than those presented in fig. 204. Meander scars were not measured on the ground but an indication of their size in a plan view can be obtained from the aerial mosaic in fig. 197 and the accompanying stereopair in fig. 198.

256. Relation of other factors. Meander scars and oxbow lakes occur on alluvial soils (fine sands, silts, and clays). They occur on terrain that is virtually flat. The features themselves cause most of the topographic relief in the area.

257. Regional distribution. These features are present in the lowlands of Nakhon Sawan, Khon Kaen, and on the Bangkok Plain, inland from the sea.

Large canals

258. This feature includes the major arteries of the man-made irrigation systems situated primarily in flat terrain.

259. Recognition on air photos.

a. Appearance. The dominant characteristic of the feature is a linear band of uniform width from which many similar but narrower bands emerge in an organized manner as though laid out and produced by mechanical means (fig. 205). These bands have either dark or very light-toned edges, depending on the amount of vegetation present. The edges enclose a uniform gray tone which indicates the presence of water. When viewed in stereo (fig. 206), the edges of the bands appear to rise above the level of the surrounding landscape.

b. Contributing elements. Large canals are an important hydrologic geometry feature in flat areas extensively cultivated in rice. Boat traffic occurs on large canals which suggests that, aside from being used for irrigation, they also serve as part of the transportation net. There are many bridges, dams, and lock systems along the course of these large canals (fig. 207).

c. Genetic description. The canals have been constructed by man to control the distribution of water to areas of intense rice cultivation.

d. Factor estimate reliability. Bank dimensions are

directly dependent upon channel configuration and water level. An estimate of bank characteristics or channel depth cannot be made from air photos of the scale used for this study.

260. Appearance on ground. Some of the main canals are over 200 ft in width and have high spoil banks on either side which usually are used by local inhabitants as roads or foot paths (fig. 208).

261. Dimensions. The cross sections presented in fig. 209 give an idea of the channel configurations and depths, which are relatively uniform throughout the length of the channel.

262. Relation to other factors. Large canals and smaller canal distributaries, forming an organized system, are found in the broad, flat areas where land is heavily cultivated in rice. Soils in these areas are usually alluvial silts and clays with some sand.

263. Regional distribution. This type of system is found in the Bangkok Plain between Lop Buri and Bangkok.

Small canals and irrigation ditches

264. These features are secondary canals and irrigation ditches which transport irrigation waters from the large canals out to the paddy areas. They are usually less than 100 ft in width.

265. Recognition on air photos.

a. Appearance. The feature is characterized by long, narrow, smoothly curved bands, usually light-toned in their centers and dark-toned along their edges (figs. 210 and 211). Each individual band tends to have a constant, uniform width extending from its junction with a large canal (a wider band) at one end to a smaller canal or ditch, or the middle of a paddy area, at the other end. When viewed stereoscopically, these bands are seen to have raised edges and depressed centers (fig. 211).

b. Contributing elements. Small canals and irrigation ditches are usually found in areas of relatively flat terrain which are cultivated in rice. Natural vegetation along the canal banks is usually dark in tone. In plan view, the regular geometric shapes (straight lines and curves with constant curvature, etc.) attest to its man-made origin. However, some small streams have been modified by man through a process of deepening and straightening for incorporation into the canal system. The altered streams often retain some of the irregular curving aspects in plan view.

c. Genetic description. These features are either man-made watercourses or natural watercourses altered by man to better control irrigation water distribution. They are primarily related to the cultivation of rice through the distribution of water, and they are also utilized as part of the transportation net.

d. Factor estimate reliability. These features are too small to permit direct evaluation of bank dimensions or channel depths from small-scale air photos. An indirect estimate could be made by inference partially based on the data acquired after measuring a number of these features on the ground.

266. Appearance on ground. The ground stereophotos in figs. 212-217, taken at the three site locations identified in fig. 210, are upstream and downstream views of these features. The spoil banks of these canals project slightly above the adjacent landscape and have associated vegetation ranging from grasses to large trees.

267. Dimensions. Channel widths (from bank top to bank top) of this type of feature are generally less than 100 ft; however, the water widths are usually much less. Cross sections of the small canals represented by locations 1, 2, and 3 in fig. 210 are presented in figs. 218 and 219. Cross sections of three irrigation ditches in the Chiang Mai area are shown in fig. 220.

268. Relation to other factors. Rice-cultivated lands having this type of irrigation distribution system usually occur on broad, flat plains of alluvial origin.

269. Regional distribution. This pattern is a characteristic hydrologic geometry feature of the Bangkok Plain. It also is present in the broad Chiang Mai valley, the plain in the vicinity of Nakhon Sawan, and to a lesser extent the plain in the vicinity of Khon Kaen.

Sinkhole ponds

270. These natural features consist of seasonally water-filled, circular depressions in landscapes related to solutioning of subsurface limestone bedrock.

271. Recognition on air photos.

a. Appearance. The predominant aspect of the air-photo

pattern is the presence of individual rounded areas, dark-toned if vegetated or very light-toned if predominately water-filled (figs. 221 and 222). The water-filled sinkholes are often sharply defined by a dark band of vegetation (fig. 222). Other light-toned circular spots in fig. 222 have indistinct edges and do not contain water; these are associated with rice-harvesting activities.

b. Contributing elements. The uniform light tone of the water in the vegetation-free depressions contributes greatly to their recognition on air photos. Vegetation (dark tones) around and within the ponds also helps in their identification. Cultural features, such as paddy or dike patterns, are adjusted to these natural depressions. Trails and roads tend to by-pass these depressions, except where a pond is used as a source of water in the area. When dry, the ponds are still usually defined by a ring of dark-toned vegetation surrounding either a dark- or light-toned center, depending upon the vegetation within the depression (fig. 223).

c. Genetic description. Sinkholes are important surface indicators of karst topography where solution processes predominate in landscape development. Some sinkholes are open and free draining, while others are plugged and filled with water.

d. Factor estimate reliability. Sinkhole ponds which exhibit most of the above-mentioned identifying criteria can be reliably identified from air photos a very high percentage of the time. Photogrammetric techniques applied to photography at a scale of 1:1000 or 1:500 could yield quantitative data as required for mobility purposes.

272. Appearance on ground. In the vast, rice-producing Bangkok Plain area, sinkhole ponds are very difficult to distinguish from the ground when the rice crop is over a foot tall. About all that is visible from the ground is a dark patch of vegetation usually associated with sinkholes (fig. 224). The ponded water associated with the feature is visible only from the very edge of the feature (fig. 225).

273. Dimensions. Sinkhole ponds are relatively shallow, but they occur in great numbers in well-developed karst areas. No cross-section data were acquired on these features. Fig. 222 presents a reasonable selection of sinkhole ponds, and the bar scale indicates their size. The dry sinkholes in fig. 222 can be used to estimate depths for other

water-filled sinkholes of approximately the same diameter.

274. Relation to other factors. Sinkhole ponds on the flat Bangkok Plain, where the alluvium is relatively thick, should contain fine-grained soils. Dark-toned brush vegetation is associated with the sinkholes on the broad Bangkok Plain. Usually the soil moisture content within a sinkhole depression remains high for a long period of time and luxurious vegetation is present within and immediately surrounding these depressions. Sinkholes in rolling karst terrain are also discussed under Surface Geometry on page 47.

275. Regional distribution. This feature occurs within and about the perimeter of the Bangkok Plain.

Small streams

276. This feature includes the networks of streams flowing from mountainous areas across broad, sloping alluvial aprons to the main trunk stream in the valley below.

277. Recognition on air photos.

a. Appearance. The pattern is created by long, narrow, crooked lines, often outlined by dark-toned vegetation in cultivated areas (fig. 226). Under stereoscopic examination (fig. 227), these lines can be seen as depressions on the landscape if dense vegetation is absent along the feature. The dense vegetation canopy often completely obscures the small streams, making the water in the channel undetectable from the air.

b. Contributing elements. Long villages with dense vegetation (trees and garden plots) occur along these streams in cultivated areas. When streams are wide and free of tall vegetation, the uniform gray tone of water in these features can be seen in air photos.

c. Genetic description. These small streams are related to the valley-filling processes by which material from the adjacent mountains is removed and redeposited as broad alluvial aprons and fans.

d. Factor estimate reliability. Mobility parameters cannot be estimated from the scale of photography presented in figs. 226 and 227. In most cases, the stream itself cannot actually be seen in these air photos but must be inferred from the presence of other indicators such as vegetation and land-use practices.

278. Appearance on ground. While no suitable ground photos were

available to illustrate this feature, its usual appearance from the ground is that of a small river or stream, with dense, tall vegetation along its banks (which generally rise a few feet above the surrounding terrain).

279. Dimensions. Numerous cross sections of this feature taken at the locations shown in fig. 226 are presented in figs. 228-230. Channel widths of these streams generally do not exceed 75 to 100 ft, while the actual width of the water is usually much less. Channel depths range from about 4 to 10 ft.

280. Relation to other factors. Gravel deposits exist in the streambeds where they emerge from the hills. Natural levees and floodplains are also associated with these streams. Vegetation is thick and tall along these watercourses.

281. Regional distribution. Small streams flowing across broad alluvial aprons can be found throughout Thailand. Striking examples of this feature occur in Chiang Mai, Khon Kaen, and Chanthaburi.

Borrow pits

282. Borrow pits occur as excavations, often filled with water, along roadways in areas where the road section is built above the level of the surrounding terrain.

283. Recognition on air photos.

a. Appearance. The chief indicator of borrow pits is narrow, elongated, light-toned lines appearing intermittently along either side of roadways or railroad right-of-ways for many miles (locations 1 and 2 in fig. 231). On larger scale photography (fig. 232) borrow pits appear as water- and vegetation-filled depressions along either side of a road.

b. Contributing elements. Roads and railroads traversing flat, rice-producing areas of Thailand have borrow pits from which soils have been excavated to raise the grade above flood level. When full of water, these pits provide farmers with water sources for irrigation purposes, and in some cases where a borrow pit system is continuous, a route of transportation. The water in a borrow pit usually has a large percentage of suspended soils and presents a light tone on panchromatic film (fig. 232). At times it is difficult to determine if a borrow pit contains

water or if the light tone is reflected from a bare, dry bottom. However, with infrared emulsions, a distinction can usually be made because surface water will have a black tone while soils and vegetation will appear lighter in tone (fig. 233).

c. Genetic description. Borrow pits are man-made features associated with the construction of roads and railroads across relatively flat terrain (fig. 234).

d. Factor estimate reliability. Cross-sectional data cannot be estimated with any reliability from stereoscopic viewing of fig. 232 because the actual bank-water contact cannot be delineated at this scale. An estimate of overall channel depth might be attempted when the feature is in a dry condition.

284. Appearance on ground. Figs. 235-237 are ground photos taken of borrow pits in the Lop Buri area. These features are full of water during the rainy season and normally are dry the remainder of the year.

285. Dimensions. Usually borrow pits are not more than 50 to 60 ft across. Cross sections of the borrow pit shown in fig. 235 and the borrow pits at locations 1 and 2 in fig. 231 are presented in fig. 238.

286. Relation to other factors. Borrow pits occur along roadways elevated above the surrounding terrain for flood-avoidance reasons. This implies that the road crosses a low or flat area subject to flooding, the soils of which most likely consist of alluvial materials (sands, silts, and clays).

287. Regional distribution. Borrow pits are associated with highway and railroad right-of-ways crossing flat or low terrain throughout Thailand.

Swamps

288. Swamps are uncultivated areas of saturated ground characterized by water- and vegetation-filled depressions usually much broader in extent than water- and vegetation-filled sinkholes.

289. Recognition on air photos.

a. Appearance. Swamps are characterized by irregularly shaped, dark-toned, uncultivated areas occupying a low position on the landscape and frequently exhibiting various stages of obliteration by vegetation (figs. 239

and 240). Often the exposed water in a swamp creates a "starlike" configuration, fringed with light tones, scattered about the floating vegetation. Except for the somewhat angular lines of the water openings, most of the detail within the feature is of a very irregular pattern and is related to the type and distribution of the vegetation in the swamp (fig. 241).

b. Contributing elements. The discontinuation of cultural activities at the edges of swamp patterns attests to their unsuitability for cultivation, and the absence of routes of transportation through these areas is evidence of their mobility significance. The irregularity of the feature identifies it as a natural pattern unaltered by man. However, many swamps in the rice-producing Bangkok Plain are being drained and cultivated (figs. 239 and 240). Frequently, the dark tones of open water within the feature, when confined and not exhibiting any visible outlet, suggest the possibility of stagnant conditions. This is contrasted with the light tones of flowing water in the silt-laden rivers and canals.

c. Genetic description. Swamps result from the accumulation of water and vegetation in depressions on the landscape in areas of impervious soils or areas having a high groundwater table. The examples in figs. 239 and 240 are found in the Lop Buri study area on the Bangkok Plain. Swamp-type vegetation growing in this feature tends to obliterate the open-water area.

d. Factor estimate reliability. With most of the above-mentioned indicators present on an air photo, a swamp can be identified a high percentage of the time. An estimate in terms required for mobility purposes of the depth of water-filled depressions from aerial photography would, at best, be an educated guess. The very nature of a swamp precludes estimation of all other hydrologic geometry parameters.

290. Appearance on ground. A ground stereopair of a swamp is shown in fig. 242. This stereopair was not taken within the area of swamp shown in figs. 239 and 240.

291. Dimensions. No ground data were obtained for swamps; however, the bar scales in figs. 239 and 240 give some indication of size of depressions.

292. Relation to other factors. Soils in swamps are normally clayey in nature and are completely saturated. Vegetation often consists of floating types (grasses, reeds), with types of water-tolerant

plants along the perimeters. Topographically, swamps represent basin-type lows on the landscape.

293. Regional distribution. Swamps exist throughout Thailand with the possible exception of the highlands where valleys are very narrow and the stream gradients steep.

Mountain streams

294. Mountain streams have no appreciable floodplain and occupy the steep, narrow valleys and major gullies of the mountainous areas of Thailand.

295. Recognition on air photos.

a. Appearance. The existence of streams of this type must be inferred on the aerial photographs because they are too small to be seen on small-scale photography such as figs. 243 and 244.

b. Contributing elements. At one time or another during the year, every V-shaped gully present in a mountain mass will contain a stream of water. Luxurious tropical mountain vegetation often obscures these streams on the aerial image. Occasionally, when mountain streams cross relatively unforested areas, their position can be traced by the dark, curved line of dense vegetation which normally occurs along the streambanks.

c. Genetic description. The existence of erosional gullies on mountains and the presence of stream channels at their bottoms are the normal factors related to the erosional cycle.

d. Factor estimate reliability. No estimate as to bank dimensions or channel depth can be made for this type feature when, in most instances, it cannot be seen on the aerial image.

296. Appearance on ground. Mountain streams, pictured in figs. 245-252, normally lie in steep-sided gullies covered with heavy tropical vegetation. The beds of such streams observed in the Chanthaburi area contained clean sands, and their currents were quite swift.

297. Dimensions. The water-filled portions of mountain stream channels are narrow (less than 50 ft in most cases). The measured stream cross sections presented in fig. 253 show representative channel shapes of the streams illustrated in figs. 246-251.

298. Relation to other factors. Mountain streams are related to

very rough and steep mountainous topography, usually having coarse-grained soils and dense forest vegetation.

299. Regional distribution. Streams such as those pictured and discussed in this section are found in every area of mountainous terrain in Thailand.

## PART VI: COMPARATIVE PHOTOGRAPHY

300. Although the major portion of the air-photo interpretation part of Project MERS was to be based on the application of current state-of-the-art techniques, it was deemed advisable to devote a small part of the effort to more experimental considerations.

301. The various components of an environment--surface and subsurface geology, soils, vegetation, hydrology, topography, cultural aspects--and the various spectral reflectance properties of different surfaces (as constantly modified by changing illumination, season, and weather) are all intimately related. They occur in characteristic associations and they display a variety of patterns based on color, brightness, and shape, that may offer insight, not only into the current physical aspects of that environment, but also into the history and present status of the natural forces operating within. How to extract this information from aerial imagery and, with assurance, relate it to other knowledge, forms the basis for much of the research in air-photo interpretation.

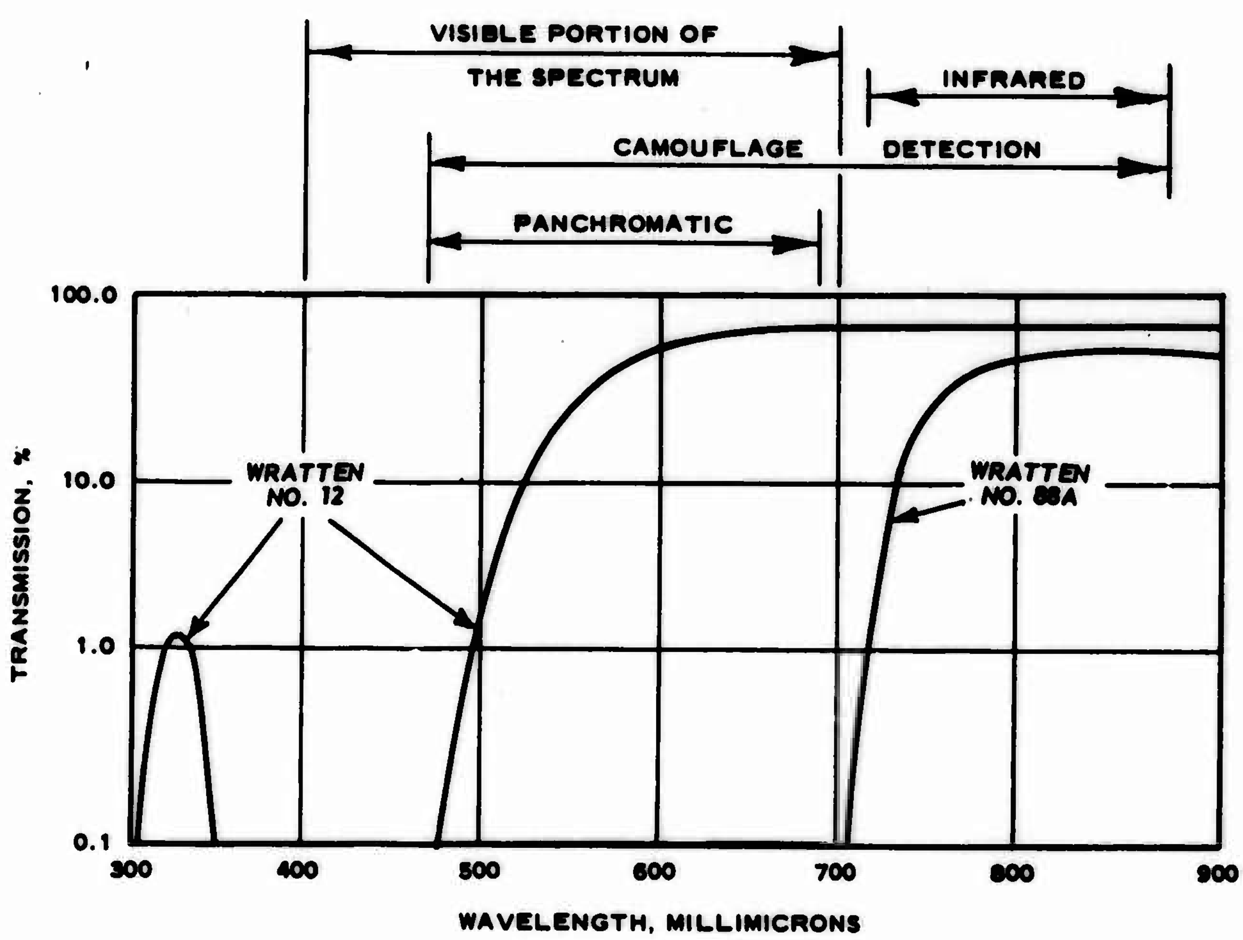
302. Which film(s), scale, and season are best suited for providing information pertinent to ground mobility in general, let alone in Southeast Asia, are questions still requiring answers. There is no reason why some aspects of ground mobility cannot be advanced by the technique of a systematic regional study coupled with the use of experimental aerial photography with panchromatic, infrared, camouflage detection, and color film. This reasoning was, in part, responsible for the decision to obtain strip photography on the primary study areas in Thailand in addition to the basic air-photo coverage.

### Films and Filters

303. At first, it was planned to evaluate four emulsions (panchromatic, infrared, camouflage detection, and color) at two scales (1:5,000 and 1:15,000) over various terrain patterns throughout the original seven study areas. Financial considerations eliminated the color photography almost at once, and later events in Thailand blocked completion of the remainder. The film-filter combinations that were used on the project are listed

below and the optical characteristics of these filters and the general film-filter responses are shown in the accompanying illustration.

| Film | Filter |
|---|---|
| Kodak Super XX Aerographic (5425). A standard panchromatic (pan) film for aerial mapping | Wratten No. 12, Minus blue. Haze cutting |
| Kodak Infrared (IR) Aerographic (5424) | Wratten No. 88A, Absorbs visual portion of the spectrum |
| Kodak Ektachrome Infrared Aero (8443). A false color reversal film for camouflage detection (CD) in forestry and vegetation studies | Wratten No. 12 |




The transmission curves show the approximate optical characteristics (from Kodak Publication No. B-3, Kodak Wratten Filters) of the Wratten filters used for the air photos. The approximate bandpasses of the film/filter combinations used are also indicated. Note that the

response of the camouflage detection film is essentially the combined response of the panchromatic and the infrared.

304. Super XX Aerographic film (type 5425) is a standard film for mapping purposes. It does not have an extended red sensitivity nor is its resolving power (in lines per millimeter) as high as that of some other panchromatic films. It was shipped by the manufacturer as a substitute item and since it was adequate for the purpose, it was accepted so that flight operations could begin. It was used with a No. 12 haze cutting filter.

305. Infrared Aerographic film (type 5424) is sensitive to energy ranging from the blue end of the visible portion of the spectrum out to wavelengths of nearly 900 millimicrons in the infrared. In order to derive whatever benefit exists in infrared photography, this film must be used with a filter that excludes a major portion, if not all, of the visible energy falling on it. Appropriate filters are the Wrattens 25A, 88A, and 89B. The characteristics of an 88A filter, the type used on this project, are shown above. The 89B filter passes a small amount of visible energy, and the 25A passes even more.

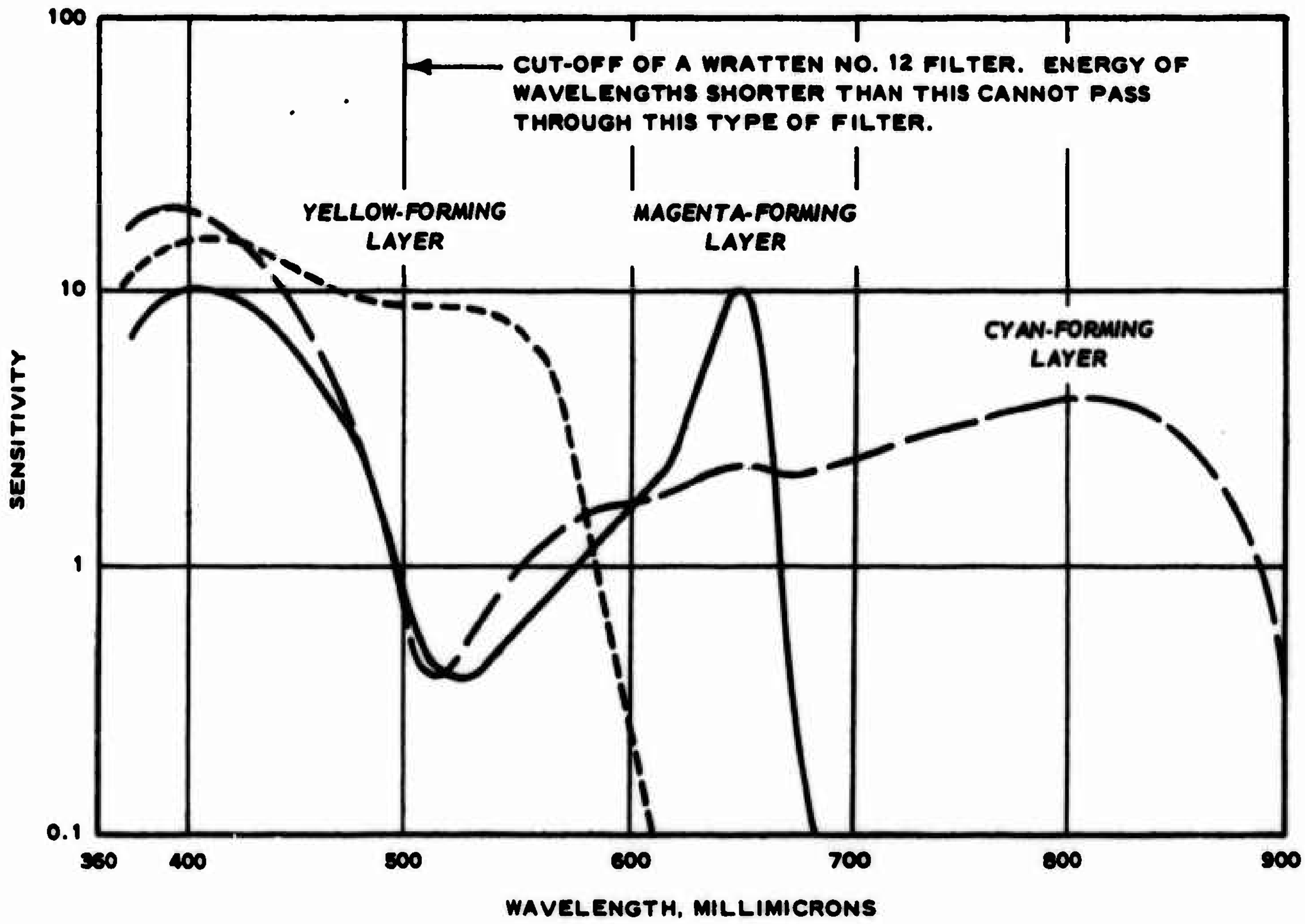
306. An annoying characteristic of infrared film is its tendency to collect and discharge static electricity, especially under conditions of low humidity. Each discharge leaves its telltale mark in the photo image. Rapid cycling of the film in the camera, as required by low-level photography, can produce a startling amount of static pattern, as can rough handling in the darkroom prior to wetting. On the asset side, this film allows greater haze penetration and presents tonal patterns different from those in panchromatic photography of the same area, thus providing a basis for correlation techniques.

307. Most healthy vegetation reflects a higher percentage of infrared radiation than of visible light. As a result, healthy plants usually show as light tones in infrared photography and as dark tones in panchromatic photography. Since the infrared reflectance of plant material is sensitive to changes in the physiological condition of the plant, infrared photography is also useful in detecting and monitoring plant disturbances--either naturally occurring or man-induced. Because

of the low infrared reflectivity of water, soil tones that arise from different moisture contents often show with greater contrast in the infrared than in the panchromatic photo region.

308. Another characteristic of infrared photography is that shadows are dark and exhibit little if any detail. During normal air-photo operations, the area of interest is illuminated by two lights, the sun and the sky. Since the shadows, caused by blockage of the sun's rays, are backlighted by sky light, most of the detail within them is apparent not only to the eye, but also to any blue sensitive film. When this light, predominantly blue in color, is removed by a filter on the camera, the information on shadow structure is removed as well.

309. Ektachrome Infrared Aero film (type 8443) is a false color film of the type that was originally designed to distinguish between the natural green of healthy vegetation and the painted green of camouflage--thus, its more common name "camouflage detection film," or CD film. It is similar to Ektachrome in that it has a green sensitive layer and a red sensitive layer. It is dissimilar in that the blue sensitive layer has been removed and an infrared sensitive layer put in its place. Since this film, when coupled to a No. 12 filter, cannot take a blue exposure, it exhibits fairly good haze penetration and also shows some loss of shadow detail, as does the black and white infrared film. During processing, each of the three layers is color coupled to produce a positive dyed image, the red sensitive layer leading to a magenta image, the green sensitive layer to a yellow image, and the infrared sensitive layer to a cyan image. The approximate sensitivities of these layers are shown in the following illustration. This information, including the lower cut-off of a No. 12 filter, was copied from a Kodak data sheet. Although the curves and above remarks are for a slightly different emulsion (8440), the general characteristics are probably similar to type 8443. The stacking of these three images into a tripack results in a color transparency that--in addition to other color shifts--shows normal vegetation as some shade of red or magenta and green paint as some shade of dark green, blue or blue-black. The principle is obviously applicable to the separation of natural and cultural pattern elements as well as




camouflage, and its potential for providing tonal contrasts that fail to register on the other films is well worth investigating.

310. It is not often that dissimilar materials, or the same material in different conditions, have the same optical characteristics in both the panchromatic and infrared portions of the photo spectrum. Thus, those surfaces that appear to be of the same brightness or color to the eye and to the panchromatic or color film may well have differences in the infrared range that can be portrayed by special films such as infrared and camouflage detection films.

## Cameras

311. Infrared aerial photography, to be of good quality, requires a different focal distance and a different lens correction than that provided by the conventional panchromatic camera. This is why much of

the available infrared photography leaves something to be desired as far as image quality is concerned; some was obtained without any alteration to the camera, and some by using the same lens but shimming the cone to correct for focal change. Recently, two companies (the Wild Corp. and the Zeiss Co.) have independently developed "universal" cameras that are suitable for both panchromatic and infrared photography. For this project, the contractor provided a Zeiss RMK camera with a 6-in. Zeiss Pleogon A lens.

## Selection of Flight Lines

312. The contract specified that three types of photography (panchromatic, infrared, and Ektachrome Infrared) be taken at scales of 1:5,000 and 1:15,000 over selected lines in all seven study areas. The lines were chosen on the basis of experience gained through analysis of earlier photography and from ground reconnaissance of the study areas. The lines were oriented in relation to location of typical surface features within an area, location of sample sites, and location of items of interest (such as the defoliation sites in Pran Buri). Table 6 lists the grid coordinates and lengths of the various proposed flight lines in the study areas. Lengths of flight lines are summarized by area in the tabulation below. The flight lines actually covered are listed in table 7.

| Area No. | Area Name | Miles of Line |
|---|---|---|
| 1 | Nakhon Sawan | 135.7 |
| 2 | Lop Buri | 156.8 |
| 3 | Chiang Mai | 106.7 |
| 4 | Pran Buri | 77.2 |
| 5 | Khon Kaen | 76.9 |
| 6 | Chanthaburi | 135.3 |
| 7 | Hat Yai | 25.0 |
| | | 713.6 |

313. Figs. 254-260 are sketches of the study areas that show the locations of these flight lines. Note in table 6 and fig. 255 for Lop Buri that flight lines 3, 5, 9, and 10 are missing. Lines 3, 5, and 10 were removed to reduce the total number of lineal miles and line 1 was extended to cover the area of old line 9.

## Summary of Completed Photography

314. The first flights for the special strip photography did not take place until February 1965. During the remaining time of the project, only a few lines were completed and these at a scale of 1:5,000. Table 7 summarizes the flights and lists the dates and times of the various photo passes. The contractor renumbered the lines as they were flown, and consequently there are two sets of line numbers.

## Factors that Delayed the Project

315. It is probably true that in any kind of field work certain characteristic events occur that tend to delay progress. With experience, one learns to identify and anticipate them and to budget time and resources accordingly. This project was no exception in having its share of delays, but some of them exceeded the original expectations.

### Communication

316. Not infrequently a situation would arise that required some kind of information from the States and vice versa; e.g., characteristics of a new filter, location of slow but needed freight or air cargo, relocation of flight lines, etc. Round-trip airmail (8-14 days) was the fastest method of relaying information. The teletype system was apparently unable to beat it. It would seem prudent, in future operations, to budget funds for use of the commercial cable (20-48 hr round trip).

### Customs

317. It is almost axiomatic that hindsight gives a certain obviousness to some events that foresight missed altogether. The time required to clear material through customs was one of these events.

Future planning ought to allow two weeks with military assistance and four weeks without military assistance for this procedure.

Weather

318. Clouds, wind, rain and storm--all obstacles to photo operations--were expected, and these expectations were generously met. However, there was one element of local weather that, though recognized, was not fully appreciated at the planning stage. This was haze. Haze characteristically develops during the dry season from dust and smoke. After the rice harvest, the fields are burned off--only a few at first but in ever-increasing numbers as the days and weeks go by. The contractor's pilot, who was familiar with this region, expressed his concern when he realized how far the project was slipping into the dry season--and predicted that it might delay the work until rains cleaned the air.

319. The insidious nature of haze is not readily apparent from the ground. In this type of air-photo operation, the pilot flies the selected line visually, checking his location by comparing the detail under the line drawn on a topographic map to that which he sees on the ground. The photographer, in turn, sets up his photo sequence by framing the ground areas in a special viewer. At the altitude of these flights, the back-scatter of sunlight from the haze particles blocked all visual references on the ground. There were many days of suitable flying weather (cloudless, with little wind), but haze prevented photo operations.

Seasonal effects

320. The seasonal effects on surface tone, color, and contrast are rather marked on the Bangkok Plain, ranging from the wet season landscape of shades of green to the dry season landscape of shades of brown, black, and green. The comparative photography was done at the peak of the dry season; most of the rice had been harvested, many of the fields burned, and the earth was dry, hard, baked, and cracked. Many of the deciduous trees were losing their leaves and much of the scrub and grass was turning brown. When these conditions are compared to those occurring in the same area during the height of the growing season, it becomes evident why photo portrayal of pattern detail, color, and tonal contrasts is both emulsion- and season-dependent.

## Results

321. A thorough analysis and discussion concerning the merits of special aerial photography as an aid to gaining information pertinent to ground mobility problems in Thailand is not feasible at this time. Aside from some of the restrictive factors--e.g., limited sample, single scale, lack of original negatives (except for CD)--a considerable amount of time and effort are needed to properly evaluate the emulsions. They must be carefully compared, frame by frame, to each other, and considered in conjunction with other data, such as reflectance measurements from field samples. The strips must then be compared to the basic coverage and analyzed and discussed with reference to each of the ground factors relevant to mobility. Obviously, this could not be done within the time frame of this report. There are, however, some general observations, comments, and recommendations that can be made at this time.

322. The photo product, both basic and strip coverage, that the contractor provided the government is good. Had air photos (even at scales of 1:20,000 or 1:40,000) been available at the beginning of this project that approached the quality of the current basic coverage, a great deal more would have been accomplished. The special Zeiss camera produced excellent quality imagery with the panchromatic and the Ektachrome Infrared (CD) films. The Infrared Aereographic photographs, although good, did not give the same visual impression of sharpness as the panchromatic.

323. It was stated earlier that there is a seasonal influence on the reflectance properties of many of the natural surfaces. This is particularly true for the rice paddies. The photo tone variations that exist within and between the fields stem from agricultural practices and represent nothing more than that. The reflecting surfaces of the fields are varied and complex, ranging through rice straw litter, short stubble, and tall stubble (each against a background of bare soil or short green grass), newly burned fields covered with a layer of black ash, old burned fields with much of the ash blown away, bare fields scraped

clean to serve as thrashing floors, and many other combinations. Since it was not possible to expose the three films simultaneously, there were delays ranging from hours to days between successive passes over the same area. Many things can happen during such an interval; rice straw can be raked up to expose green grass, fields can be burned off, etc. When evaluating comparative photography of such an area, these factors should be kept in mind.

324. Figs. 261 and 262 are examples of panchromatic and infrared photographs, respectively, of burned field patterns, although not of the complexity described. The harvest season was well over at the time of these photographs and the fields were either cut and raked or burned. The ash from the burning is black in both portions of the spectrum, although less so in the panchromatic region as evidenced by the detail within the burned fields on the panchromatic photo; it is even possible to infer something of the order of burning of the fields from this photo.

325. During this part of the dry season (February), the surface was as stripped or devoid of vegetation as it will ever be, and the photographs clearly show the dike pattern, roads, trails (temporary or otherwise), small drainage channels, footpaths, and similar surface detail. Figs. 263 and 264 are examples of this (as are figs. 261 and 262), and they also demonstrate the fact that the paddy/dike pattern is sharper and more apparent in the panchromatic than it is in the infrared (IR) photography. The trails and footpaths show clearly in both emulsions, sometimes favoring one over the other as a function of the brightness of the local soil compared to the adjacent straw or grass. Since the trails and paths are bare ground, some information can be gained about the soil's gross reflectance properties in these two parts of the spectrum. The large bright spots (both rectangular and round) are bare ground areas that were used as threshing floors. The Ektachrome Infrared film (CD) depicted all these--dikes, trails, vegetation, etc.--with even greater clarity and sharpness than the panchromatic emulsion and provided other information such as amount of new grass coming up in the paddies and the presence or absence of water in some of the small wells. If dike structure or other microrelief

features are to be studied by photogrammetric procedures or by the use of a laser profiler, or equivalent, the latter part of the dry season is the best time to do it.

326. Figs. 265 and 266 are examples of panchromatic and infrared (IR) photography of water features. Many of the confined bodies of water and small canals had a high concentration of suspended silt. As the dry season progressed, more water was lost, and that remaining contained even more silt; some of the ponds could be better described as liquid mud. The various amounts and color of suspended material gave the water different hues and brightnesses. To the eye, some of the ponds appeared clear while others seemed to blend in with adjacent banks. In the photographs selected for figs. 265 and 266 the water bodies are readily identified. The two large square ponds above the highway, near the center line of the photo, show the influence of silt on the photographic response. Both ponds contained silt. The one on the right had the largest amount and shows as a light tone in both photos. The pond on the left had enough less silt so that its infrared reflectance property was more typical of water and it gave the infrared photo response expected. The small ponds in the lower left-hand quadrant show an analogous series of tones. It is likely that there are silt/water mixtures that neither the panchromatic nor the infrared could positively separate from the adjacent soil banks. The Ektachrome Infrared (CD) film was superior to the other films in bounding water locations accurately and with contrast--impressively so. The clear waters, or water of little silt content, show as a vivid blue; as the silt content increases the blue takes on a slate color. The slightest vegetation around the edge shows as red tones, and the bare soils seem to resemble their natural colors of browns, tans, and dark grays. The small rectangles (black in the panchromatic and white in the infrared) to the left of the canal near the bottom center (figs. 265 and 266) are new seed beds of rice. They are an intense red color in the Ektachrome Infrared film. The broad darkish bank on both sides of the canal, tending from lower center to upper right, marks the damage from the standing water of the flood of 1964.

## Conclusions

327. All three emulsions provided good quality imagery. The tone changes that exist between the different films have meaning, some of it understood but much of it not. A considerable amount of field work and laboratory work will be required before it can be said that most of it is understood. For this type of research, the simultaneous use of different film/filter combinations is necessary. Once the details have been worked out and the elements of the various images have all been related to patterns and conditions on the ground, and their meaning known with confidence, then it will be possible to select the correct film or films for any given task.

328. Of the three films, the panchromatic and the Ektachrome Infrared (CD) are the best and will prove to be a most useful combination for many air-photo studies. The quality of the Ektachrome Infrared (CD) film was excellent on all counts: sharpness, detail, color and tone separation. With further field and laboratory work to develop a thorough understanding of it, this film may vie with panchromatic film for all-around usefulness. Its image quality is sensitive to exposure and processing control, and there is the disadvantage that it must be used as a film (no paper prints) and, as such, requires special handling, special viewers, and other equipment.

329. When it is desired to obtain general information without regard to season or scale and when work prints are needed for field use, etc., the panchromatic emulsion, although not necessarily Super XX, is the best choice.

## Recommendations

330. Scale was not studied as such, but some comments are in order. The evaluation of large surface features and gross pattern elements from small-scale photography provides the clues and basis for understanding the relation, composition, and characteristics that pertain to the smaller components as seen in large-scale photography. Good quality 1:40,000 or

1:20,000 panchromatic coverage is the first prerequisite for any study.

331. With this in mind, some specific statements can be made concerning the choice of film for gaining information about the four terrain-factor families. Films recommended for the respective factor families are listed below in order of preference.

| Factor Family | Film | Remarks |
|---|---|---|
| Soil composition | Panchromatic, Ektachrome Infrared (CD), infrared | Soil surfaces will be most exposed during the dry season |
| Surface geometry | Panchromatic, Ektachrome Infrared (CD) | Best results in the late dry season |
| Hydrologic geometry | Ektachrome Infrared (CD), infrared | |
| Vegetation | Panchromatic, Ektachrome Infrared (CD) | |

332. In spite of several attempts over the years, an evaluation of films of the same area at different scales and made using different emulsions (panchromatic, infrared, camouflage detection, and color) has not been accomplished. It is worth doing, for an emulsion may give very useful tonal separations at one scale but contribute little at another scale, and these characteristics are not fully known.

333. The area selected for such a study must be small enough to avoid the creation of a data-handling problem but large enough to contain several elements of pattern. A 5- by 5-mile area might be adequate.

334. The four films should be flown at each of the selected scales and as near the same time as possible. A complete series of films should be made of the same area at the peak of the wet season, at the peak of the dry season, and at some time between. The preliminary evaluation should be made by a ground team which remained at the site throughout the project. The use of a small area would allow the team to become intimately familiar with all aspects of that particular environment. This would not only enhance the field evaluation, but would be of great help during

the laboratory phase and write-up. Recommended films and scales are listed below.

| | |
|---|---|
| Films: | Plus-X Aerographic (panchromatic)<br>Infrared Aerographic<br>Ektachrome Infrared Aero<br>Ektachrome Aero (high altitude)<br>Special Ektachrome Aerial (low altitude) |
| Scale: | 1:40,000<br>1:15,000<br>1:5,000<br>1:2,500 - selected areas only |
| Camera: | The Wild or Zeiss Universal with a 6-in. lens |

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## ORGANIZATION OF TABLES AND FIGURES

# INTRODUCTION

Table 1

Terrain Factors Affecting Vehicle Performance

| Terrain Factor Family | Terrain Factor | Unit of Measure | Class Ranges 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface composition* | Soil mass strength | RCI | <10 | 10-25 | >25-60 | >60-100 | >100 | | | | |
| | Soil surface strength | psi | 0-1 | >1-2 | >2-4 | 0-1 | >1-2 | >2-4 | 0-1 | >1-2 | >2-4 |
| | | deg | 0-10 | 0-10 | 0-10 | >10-20 | >10-20 | >10-20 | >20-40 | >20-40 | >20-40 |
| Surface geometry | Slope | deg | 0-1.5 | >1.5-4.5 | >4.5-9 | >9-18 | >18-30 | >30-45 | >45 | | |
| | Vertical obstacle spacing | ft | 0-7 | >7-12 | >12-50 | >50-150 | >150 | | | | |
| | Terrain approach angle | deg | <100 | 100-<125 | 125-<150 | 150-<165 | 165-<180 | 180-<200 | 200-<210 | 210-<220 | |
| | Step height** | in. | 0-4 | >4-10 | >10-18 | >18-30 | >30-48 | >48-66 | >66-84 | >84 | |
| Vegetation† | Spacing of stems ≤ 2, 5, 9, and 50 in. in diameter | ft | >30 | >10-30 | >5-10 | 0-5 | | | | | |
| | Spacing of stems ≥ 1, 3, 6, and 10 in. in diameter | ft | >30 | >10-30 | >5-10 | 0-5 | | | | | |
| Hydrologic geometry†† | Contact approach angle | deg | <145 | 145-155 | >155-165 | >165-180 | | | | | |
| | Step height** | in. | <12 | 12-<24 | 24-<36 | 36-48 | >48 | | | | |
| | Position of step base‡ | in. | 48 bwl‡‡ | >36-48 bwl | >18-36 bwl | 1-18 bwl | At water level | 1-12 awl§ | >12-30 awl | >30-48 awl | >48 awl |
| | Water depth | ft | 3-4.5 | >4.5 | | | | | | | |

* Maximum and minimum moisture conditions mapped.
** Step is a slope change >35°. Absence of step is shown by "X."
† Class ranges for each diameter are mapped.
†† Mean maximum and mean minimum water mapped.
‡ Referenced to water level.
‡‡ Below water level.
§ Above water level.

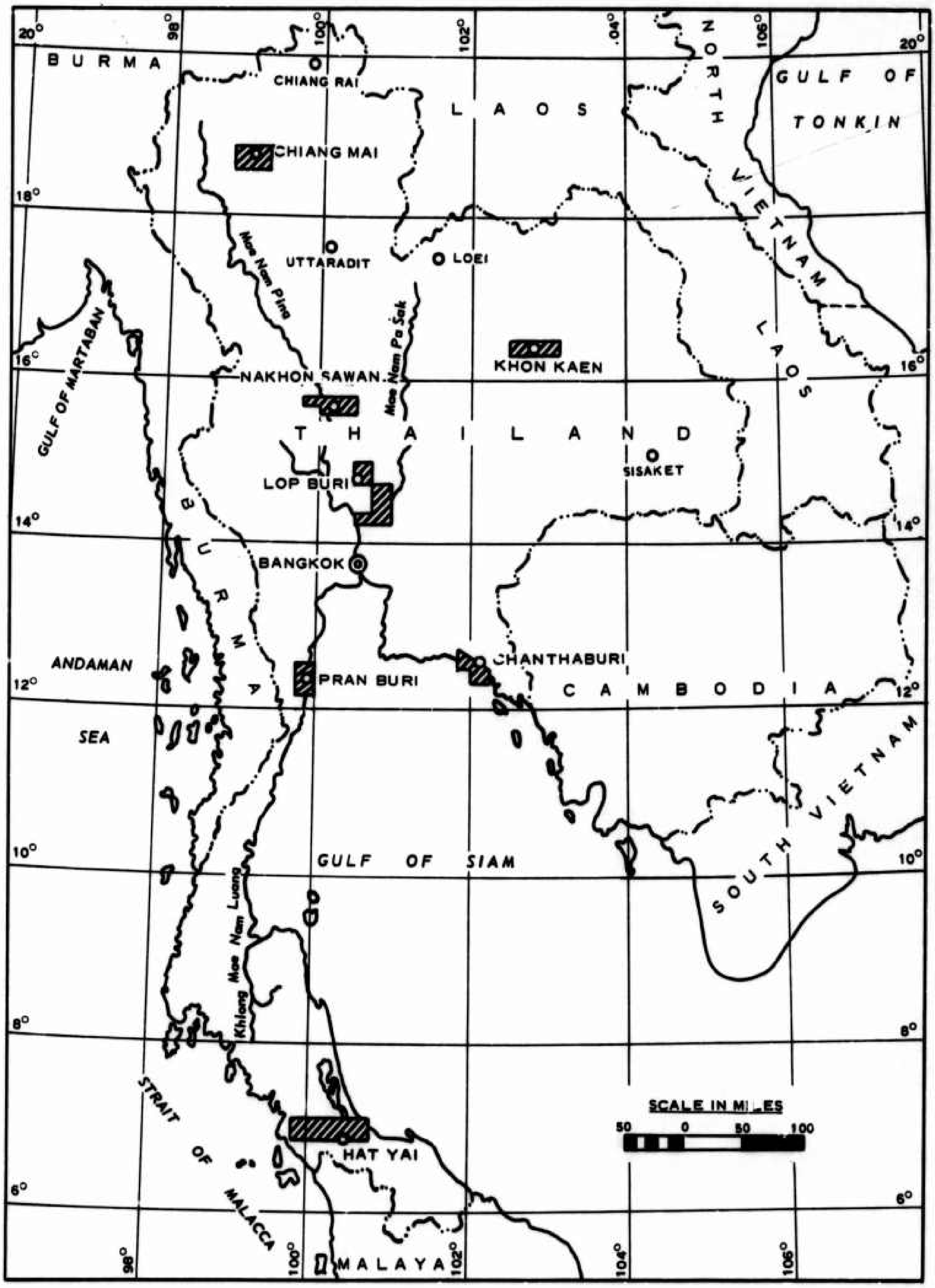



Fig. 1. Thailand study areas

# SURFACE COMPOSITION

Table 2

Surface Composition

Summary of Soil Data

| Site | Date of Sample | Location: Map Sheet* | Location: Grid Coordinates | Depth of Layer in. | Organic Matter % | U. S. Department of Agriculture: Gvl % by Vol | Texture by Wt, %: Sand | Silt | Clay | Type | Unified Soil Classification System: Fines % by Wt | Atterberg Limits: LL % | PL % | PI % | Type | Specific Gravity | Moisture Content % | Strength Measurements: Cone Index (CI) | Remolding Index (RI) | Rating Cone Index (RCI) | Sheargraph**: $\alpha_{ur}$ deg | $\phi_u$ deg | $a_{ur}$ psi | $c_u$ psi | Photo Illustrations, Fig.: Air Photo | Ground Photo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | **Bangkok Clay** | | | | | | | | | | | | | | |
| 2 | 9-4-64 | 5153IV | 820785 | 0-6 | 2.41 | 0 | 5 | 67 | 28 | SiCL | 97 | 57 | 29 | 28 | CH | 2.65 | 21.8 | 124 | -- | -- | -- | -- | -- | -- | 6, 7 | -- |
| | | | | 6-12 | 0.97 | 0 | 7 | 67 | 26 | SiL | 95 | 69 | 25 | 44 | CH | 2.74 | 28.0 | 143 | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-T-1 | 6-13-64 | 5153IV | 825794 | 0-12 | -- | 0 | 6 | 62 | 32 | SiCL | 96 | 61 | 23 | 38 | CH | 2.65 | -- | 90 | -- | -- | 10 | 32 | 3.2 | 2.2 | 6, 7 | -- |
| 2-T-4 | 6-23-64 | 5153IV | 786804 | 0-6 | -- | 0 | 15 | 50 | 35 | SiCL | 89 | 62 | 27 | 35 | CH | 2.69 | -- | 157 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | 6-12 | -- | 0 | 18 | 48 | 34 | SiCL | 86 | 60 | 26 | 34 | CH | 2.76 | -- | 110 | -- | -- | -- | -- | -- | -- | 6 | -- |
| | | | | | | | | | | | | **Ongkharak Clay** | | | | | | | | | | | | | | |
| 31 | 9-15-64 | 5153I | 948788 | 0-6 | 1.65 | 0 | 16 | 62 | 32 | SiL | 89 | 68 | 31 | 37 | CH | 2.71 | 35.0 | 82 | -- | -- | -- | -- | -- | -- | 9, 10, 11 | 12 |
| | | | | 6-12 | 0.87 | 0 | 17 | 56 | 27 | SiL | 87 | 62 | 27 | 35 | CH | 2.69 | 34.6 | 91 | 0.83 | 76 | -- | -- | -- | -- | -- | -- |
| 33 | 9-16-64 | 5153I | 963793 | 0-6 | 4.70 | 0 | 18 | 54 | 28 | SiCL | 87 | 73 | 44 | 29 | MH | 2.58 | 44.9 | 85 | -- | -- | -- | -- | -- | -- | 9, 10, 11 | 13 |
| | | | | 6-12 | .20 | 0 | 22 | 47 | 31 | CL | 83 | 79 | 39 | 40 | MH | 2.59 | 41.6 | 150 | 0.99 | 149 | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | **Tachin Clay** | | | | | | | | | | | | | | |
| 124 | 10-8-64 | 5448III | 874790 | 0-6 | 2.41 | 0 | 18 | 74 | 8 | SiL | 92 | 32 | 23 | 9 | CL | 2.60 | -- | -- | -- | -- | -- | -- | -- | -- | 14, 15 | 17 |
| | | | | 6-12 | 4.38 | 0 | 20 | 72 | 8 | SiL | 89 | 32 | 26 | 6 | ML | 2.57 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 126 | 10-9-64 | 5448III | 897782 | 0-6 | 8.98 | 0 | 22 | 62 | 16 | SiL | 84 | 73 | 42 | 31 | OH | 2.55 | 100.2 | 19 | -- | -- | -- | -- | -- | -- | 14, 15 | -- |
| | | | | 6-12 | 6.27 | 0 | 30 | 62 | 8 | SiL | 83 | 64 | 36 | 28 | MH | 2.58 | 77.7 | 37 | 0.52 | 19 | -- | -- | -- | -- | -- | -- |
| 127 | 10-9-64 | 5448III | 895783 | 0-6 | 5.09 | 0 | 16 | 72 | 12 | SiL | 90 | 60 | 33 | 27 | MH | 2.55 | 52.7 | 41 | -- | -- | -- | -- | -- | -- | 14, 15 | 18 |
| | | | | 6-12 | 6.20 | 0 | 18 | 72 | 10 | SiL | 90 | 67 | 32 | 35 | CH | 2.61 | 59.6 | 56 | 0.94 | 53 | -- | -- | -- | -- | -- | -- |
| 143 | 10-11-64 | 5448IV | 804875 | 0-6 | 15.32 | 0 | 55 | 40 | 5 | SL | 56 | 60 | 38 | 22 | OH | 2.33 | 63.0 | 56 | -- | -- | -- | -- | -- | -- | 14, 16 | -- |
| | | | | 6-12 | 17.70 | 0 | 41 | 50 | 9 | SiL | 68 | 80 | 46 | 34 | OH | 2.32 | 99.8 | 29 | 0.49 | 14 | -- | -- | -- | -- | -- | -- |
| 144 | 10-11-64 | 5448IV | 811869 | 0-6 | 7.25 | 0 | 36 | 49 | 15 | L | 76 | 45 | 13 | 32 | CL | 2.49 | 32.0 | 123 | -- | -- | -- | -- | -- | -- | 14, 16 | 19, 20 |
| | | | | 6-12 | 5.02 | 0 | 39 | 44 | 17 | L | 71 | 49 | 27 | 22 | CL | 2.50 | 44.0 | 82 | 0.73 | 60 | -- | -- | -- | -- | -- | -- |
| 145 | 10-11-64 | 5448IV | 812917 | 0-6 | 1.20 | 0 | 50 | 40 | 10 | L | 65 | 21 | 21 | 0 | ML | 2.72 | 23.3 | 97 | -- | -- | -- | -- | -- | -- | 14, 16 | -- |
| | | | | 6-12 | 0.91 | 0 | 37 | 48 | 15 | L | 75 | 26 | 17 | 9 | CL | 2.67 | 45.6 | 51 | 0.64 | 33 | -- | -- | -- | -- | -- | -- |

(Continued)

Note: $\alpha_{ur}$ - ultimate soil-to-rubber angle of friction,
$\phi_u$ - ultimate soil-to-soil angle of internal friction,
$a_{ur}$ - ultimate soil-to-rubber adhesion, and
$c_u$ - ultimate soil-to-soil cohesion.

* Army Map Service, L708, 1:50,000.

** All readings were made at the soil surface.

Table 2 (Continued)

| Site | Date of Sample | Location: Map Sheet | Location: Grid Co-ordinates | Depth of Layer in. | Organic Matter % | U.S. Dept. of Agriculture: Gvl % by Vol | Texture by Wt. %: Sand | Silt | Clay | Type | Unified Soil Classification System: Fines % by Wt | Atterberg Limits: LL % | PL % | PI % | Type | Specific Gravity | Moisture Content % | Strength Measurements: Cone Index (CI) | Remolding Index (RI) | Rating Cone Index (RCI) | Sheargraph: $\alpha_{ur}$ deg | $\phi_u$ deg | $a_{ur}$ psi | $c_u$ psi | Photo Illustrations, Fig.: Air Photo | Ground Photo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | **Tachin Clay (Continued)** | | | | | | | | | | | | | | | |
| 187 | 10-17-64 | 5448IV | 815992 | 0-6 | 8.55 | 0 | 40 | 53 | 7 | SiL | 75 | 43 | 25 | 18 | OL | 2.49 | 40.2 | 33 | -- | -- | -- | -- | -- | -- | 14, 16 | -- |
| | | | | 6-12 | 12.67 | 0 | 42 | 46 | 12 | L | 69 | 59 | 34 | 25 | OH | 2.44 | 91.2 | 18 | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | **Lop Buri Clay** | | | | | | | | | | | | | | | |
| 59 | 9-19-64 | 5154IV | 88116 | 0-6 | -- | 0 | 11 | 68 | 21 | SiL | 93 | 80 | 30 | 50 | CH | 2.79 | 42.9 | 49 | -- | -- | -- | -- | -- | -- | 21, 22, 23 | 26 |
| | | | | 6-12 | -- | 0 | 9 | 69 | 22 | SiL | 95 | 88 | 30 | 58 | CH | 2.78 | 47.2 | 50 | 1.28 | 64 | -- | -- | -- | -- | -- | -- |
| 60 | 9-19-64 | 5154IV | 881164 | 0-6 | -- | 0 | 22 | 73 | 5 | SiL | 84 | 61 | 22 | 39 | CH | 2.69 | 30.5 | 93 | -- | -- | -- | -- | -- | -- | 21, 22, 23 | 26 |
| | | | | 6-12 | -- | 0 | 17 | 73 | 10 | SiL | 87 | 62 | 26 | 36 | CH | 2.57 | 27.5 | 110 | 1.16 | 128 | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | **Chiang Mai Loam** | | | | | | | | | | | | | | | |
| 3T11 | 10-9-64 | 4867IV | 049832 | 0-12 | 0.62 | 0 | 66 | 15 | 19 | SL | 58 | 34 | 25 | 9 | ML | -- | -- | 230 | -- | -- | 28 | 23 | 1.8 | 3.2 | 29, 30 | -- |
| 3T14 | 10-9-64 | 4867IV | 036800 | 0-12 | 1.55 | 0 | 57 | 28 | 15 | SL | 52 | 35 | 22 | 13 | CL | -- | -- | 73 | -- | -- | 9 | 19 | 2.5 | 2.4 | 29, 30 | -- |
| 21F | 9-13-64 | 4867IV | 031795 | 6-12 | 0.78 | 0 | 66 | 20 | 14 | SL | 46 | 24 | 17 | 7 | SM-SC | -- | 21.9 | 142 | 0.36 | 51 | 18 | 19 | 0.3 | 1.5 | 29, 30 | -- |
| 21F | 9-13-64 | 4867IV | 031795 | 6-12 | 2.30 | 0 | 86 | 9 | 5 | LS | 20 | -- | -- | NP | SM | -- | 18.8 | 308 | 0.24 | 91 | -- | -- | -- | -- | 29, 30 | -- |
| 22A | 9-14-64 | 4866IV | 014533 | 6-12 | 1.40 | 0 | 40 | 31 | 29 | CL | 76 | 31 | 17 | 14 | CL | 2.68 | 22.8 | 111 | 0.53 | 59 | 8 | 16 | 0.5 | 1.5 | 31, 32 | -- |
| 22B | 9-14-64 | 4866IV | 015533 | 6-12 | 2.30 | 7 | 15 | 46 | 39 | SiCl | 88 | 47 | 23 | 24 | CL | -- | 33.4 | 48 | 0.54 | 26 | 10 | 10 | 0.4 | 1.0 | 31, 32 | -- |
| 22C | 9-14-64 | 4866IV | 015533 | 6-12 | 1.90 | 0 | 30 | 40 | 30 | CL | 78 | 40 | 21 | 19 | CL | -- | 21.5 | 84 | 0.73 | 61 | 11 | 21 | 0.7 | 1.7 | 31, 32 | -- |
| 22E | 9-14-64 | 4866IV | 027530 | 6-12 | 1.25 | 0 | 12 | 63 | 25 | SiL | 91 | 34 | 28 | 12 | CL | -- | 24.3 | 313 | 0.25 | 78 | 2 | 18 | 0.2 | 0.7 | 31, 32 | -- |
| 3T25 | 10-22-64 | 4866IV | 022536 | 0-12 | 0.74 | 0 | 40 | 36 | 24 | L | 72 | 28 | 17 | 11 | CL | -- | -- | 146 | 0.79 | 116 | 27 | 29 | 2.0 | 4.1 | 31, 32 | -- |
| 3T32 | 10-23-64 | 4766I | 993544 | 0-12 | 1.35 | 0 | 23 | 41 | 36 | CL | 84 | 37 | 25 | 12 | ML | -- | -- | 108 | 0.73 | 79 | 23 | 27 | 1.8 | 3.3 | 31, 32 | -- |
| | | | | | | | | | | | **Chanthaburi Clay** | | | | | | | | | | | | | | | |
| 116 | 10-7-64 | 5448IV | 770991 | 0-6 | 4.61 | 0 | 82 | 9 | 9 | LS | 59 | 60 | 41 | 19 | MH | 2.73 | 49.8 | 110 | -- | -- | -- | -- | -- | -- | 33, 34 | -- |
| | | | | 6-12 | 1.83 | 0 | 77 | 16 | 7 | LS | 60 | 52 | 33 | 19 | MH | 2.72 | 44.5 | 133 | 1.02 | 136 | -- | -- | -- | -- | -- | -- |
| 146 | 10-11-64 | 5448IV | 757002 | 0-6 | 2.23 | 0 | 54 | 38 | 8 | SL | 48 | 43 | 25 | 18 | SC | 2.60 | 24.6 | 158+ | -- | -- | -- | -- | -- | -- | 33, 34 | -- |
| | | | | 6-12 | 2.03 | 0 | 47 | 45 | 8 | L | 59 | 38 | 23 | 15 | CL | 2.51 | 22.6 | 290+ | 0.46 | 133+ | -- | -- | -- | -- | -- | -- |
| 147 | 10-11-64 | 5448IV | 757993 | 0-6 | 2.06 | 0 | 61 | 35 | 4 | SL | 46 | 23 | 20 | 13 | SM | 2.59 | 24.6 | 94 | -- | -- | -- | -- | -- | -- | 33, 34 | -- |
| | | | | 6-12 | 1.55 | 5 | 57 | 36 | 7 | SL | 47 | 23 | -- | NP | SM | 2.58 | 17.6 | 170+ | 0.60 | 102+ | -- | -- | -- | -- | -- | -- |
| 148 | 10-11-64 | 5448IV | 752981 | 0-6 | 3.48 | 3 | 47 | 37 | 16 | L | 57 | 54 | 35 | 19 | MH | 2.65 | 33.8 | 150 | -- | -- | -- | -- | -- | -- | 33, 34 | -- |
| | | | | 6-12 | 1.45 | 5 | 55 | 36 | 9 | SL | 50 | 46 | 35 | 11 | ML | 2.66 | 26.2 | 300+ | 0.97 | 291+ | -- | -- | -- | -- | -- | -- |
| 149 | 10-11-64 | 5448IV | 773974 | 0-6 | 2.54 | 0 | 41 | 49 | 10 | L | 70 | 58 | 47 | 11 | MH | 2.92 | 45.5 | 229 | -- | -- | -- | -- | -- | -- | 33, 34 | 35 |
| | | | | 6-12 | 1.20 | 0 | 56 | 30 | 14 | SL | 53 | 63 | 47 | 16 | MH | 2.93 | 41.6 | 217 | 1.29 | 279 | -- | -- | -- | -- | -- | -- |
| 151 | 10-12-64 | 5448IV | 790998 | 0-6 | 3.14 | 0 | 37 | 51 | 12 | SiL | 72 | 58 | 44 | 14 | MH | 2.70 | 44.9 | 195 | -- | -- | -- | -- | -- | -- | 33, 34 | -- |
| | | | | 6-12 | 1.93 | 0 | 51 | 37 | 12 | L | 59 | 60 | 29 | 31 | CH | 2.74 | 42.8 | 216 | -- | -- | -- | -- | -- | -- | -- | -- |

(Continued)

(2 of 3 sheets)

Table 2 (Concluded)

| Site | Date of Sample | Location: Map Sheet | Location: Grid Co-ordinates | Depth of Layer in. | Organic Matter % | Classification: U. S. Department of Agriculture: Gvl % by Vol | Texture by Wt, %: Sand | Texture by Wt, %: Silt | Texture by Wt, %: Clay | Type | Unified Soil Classification System: Fines % by Wt | Atterberg Limits: LL % | PL % | PI % | Type | Specific Gravity | Moisture Content % | Strength Measurements: Cone Index (CI) | Remolding Index (RI) | Rating Cone Index (RCI) | Sheargraph: $\phi_r$ deg | $\phi_u$ deg | $c_{ur}$ psi | $c_u$ psi | Photo Illustrations, Fig.: Air Photo | Ground Photo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | **Chanthaburi Clay (Continued)** | | | | | | | | | | | | | | | |
| 152 | 10-12-64 | 5448IV | 788[illegible]1 | 0-6 | 3.55 | 0 | 55 | 26 | 19 | SL | 51 | 44 | 29 | 15 | ML | 2.58 | 25.6 | 104 | -- | -- | -- | -- | -- | -- | 33, 34 | -- |
| | | | | 6-12 | 2.22 | 0 | 63 | 24 | 13 | SL | 44 | 41 | 26 | 15 | SM | 2.61 | 22.2 | 159 | 1.23 | 196 | -- | -- | -- | -- | -- | -- |
| 154 | 10-12-64 | 5448IV | 783984 | 0-6 | 2.35 | 0 | 59 | 32 | 9 | SL | 53 | 58 | 47 | 11 | MH | 2.75 | 54.4 | 56 | -- | -- | -- | -- | -- | -- | 33, 34 | -- |
| | | | | 6-12 | 2.11 | 0 | 48 | 37 | 15 | L | 61 | 57 | 44 | 13 | MH | 2.78 | 52.8 | 94 | 1.52 | 143 | -- | -- | -- | -- | -- | -- |
| 168 | 10-14-64 | 5448IV | 780997 | 0-6 | 2.42 | 0 | 35 | 52 | 13 | SiL | 76 | 65 | 46 | 19 | MH | 2.73 | 53.0 | 130 | -- | -- | -- | -- | -- | -- | 33, 34 | -- |
| | | | | 6-12 | 2.12 | 0 | 52 | 38 | 10 | L | 56 | 57 | 44 | 13 | MH | 2.81 | 48.5 | 131 | 0.46 | 60 | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | **Natural Levee** | | | | | | | | | | | | | | | |
| 16A | 9-4-64 | 5154I | 122126 | 6-12 | 0.78 | 0 | 50 | 35 | 15 | L | 71 | 28 | 22 | 6 | CL-ML | 2.66 | 14.0 | 390 | 0.95 | 370 | 18 | 22 | 0 | 1.0 | 37 | -- |
| 16B | 9-4-64 | 5154I | 123125 | 6-12 | 1.10 | 0 | 57 | 28 | 15 | SL | 60 | 27 | 23 | 4 | ML | -- | 15.9 | 356 | 1.07 | 381 | 18 | 26 | 0 | 0 | 37 | -- |
| 17 | 9-8-64 | 5154I | 023087 | 0-6 | 1.15 | 0 | 23 | 67 | 10 | SiL | 83 | 38 | 28 | 10 | ML | 2.71 | 21.4 | 112 | -- | -- | -- | -- | -- | -- | 37 | 42 |
| | | | | 6-12 | 0.51 | 0 | 25 | 62 | 13 | SiL | 81 | 47 | 20 | 27 | CL | 2.70 | 24.6 | 66 | -- | -- | -- | -- | -- | -- | -- | -- |
| 19 | 9-14-64 | 5154I | 045089 | 0-6 | 1.00 | 0 | 14 | 66 | 20 | SiL | 90 | 52 | 25 | 27 | CH | 2.67 | 29.6 | 42 | -- | -- | -- | -- | -- | -- | 37, 38 | 40 |
| | | | | 6-12 | 0.70 | 0 | 13 | 65 | 22 | SiL | 92 | 54 | 24 | 30 | CH | 2.67 | 24.5 | 10[illegible] | 0.93 | 95 | -- | -- | -- | -- | -- | -- |
| 20 | 9-14-64 | 5154I | 048093 | 0-6 | 1.10 | 0 | 20 | 67 | 13 | SiL | 85 | 35 | 22 | 13 | CL | 2.72 | 28.8 | 37 | -- | -- | -- | -- | -- | -- | 37, 38 | 41 |
| | | | | 6-12 | 0.74 | 0 | 7 | 65 | 28 | SiL | 94 | 57 | 22 | 35 | CH | 2.64 | 28.1 | 101 | 0.43 | 43 | -- | -- | -- | -- | -- | -- |
| 49 | 9-18-64 | 5154I | 123124 | 0-6 | 1.10 | 0 | 59 | 32 | 9 | SL | 58 | 27 | 26 | 1 | ML | 2.61 | 22.0 | 103+ | -- | -- | -- | -- | -- | -- | 37 | -- |
| | | | | 6-12 | -- | 0 | 58 | 35 | 7 | SL | 58 | 21 | -- | NP | ML | 2.65 | 20.6 | 172+ | 0.46 | 79+ | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | **Beach Ridge** | | | | | | | | | | | | | | | |
| 122 | 10-8-64 | 5448III | 812812 | 0-6 | 0.12 | 0 | 100 | 0 | 0 | S | 0 | -- | -- | NP | SP | 2.69 | -- | -- | -- | -- | -- | -- | -- | -- | 43, 44 | 46 |
| 123 | 10-8-64 | 5448III | 821811 | 0-6 | 0.39 | 0 | 100 | 0 | 0 | S | 0 | -- | -- | NP | SP | 2.63 | -- | -- | -- | -- | -- | -- | -- | -- | 43, 44 | -- |
| | | | | 6-12 | 0.18 | 0 | 100 | 0 | 0 | S | 0 | -- | -- | NP | SP | 2.65 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 133 | 10-10-64 | 5448IV | 866877 | 0-6 | 1.15 | 0 | 84 | 14 | 2 | LS | 20 | -- | -- | NP | SM | 2.63 | 12.7 | 120 | -- | -- | -- | -- | -- | -- | 43, 45 | -- |
| | | | | 6-12 | 0.71 | 0 | 81 | 17 | 2 | LS | 23 | -- | -- | NP | SM | 2.65 | 13.4 | 116 | -- | -- | -- | -- | -- | -- | -- | -- |
| 134 | 10-10-64 | 5448IV | 874886 | 0-6 | 0.44 | 3 | 100 | 0 | 0 | S | 0 | -- | -- | NP | SP | 2.64 | -- | -- | -- | -- | -- | -- | -- | -- | 43, 45 | 47 |
| | | | | 6-12 | 0.22 | 3 | 100 | 0 | 0 | S | 0 | -- | -- | NP | SP | 2.65 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | **Abandoned Channel** | | | | | | | | | | | | | | | |
| 12D | 8-30-64 | 5154II | 025877 | 6-12 | 2.30 | 0 | 12 | 46 | 42 | SiC | 94 | 46 | 22 | 24 | CL | -- | 38.4 | 65 | 0.82 | 53 | 12 | 18 | 0.2 | 1.2 | 49, 50, 51 | 53 |
| 2-T-15 | 6-25-64 | 5154II | 020875 | 0-7 | -- | 0 | 6 | 60 | 34 | SiCL | 96 | 46 | 26 | 20 | CL | 2.68 | -- | 88 | -- | -- | -- | -- | -- | -- | 49, 50, 51 | 52 |
| | | | | 7-12 | -- | 0 | 12 | 58 | 30 | SiCL | 92 | 45 | 25 | 20 | CL | 2.73 | -- | 203 | -- | -- | -- | -- | -- | -- | -- | -- |
| 89 | 9-28-64 | 5154II | 025884 | 0-6 | -- | 0 | 14 | 63 | 23 | SiL | 91 | 39 | 21 | 18 | CL | 2.62 | -- | 102 | -- | -- | -- | -- | -- | -- | 49, 50, 51 | -- |
| | | | | 6-12 | -- | 0 | 15 | 60 | 25 | SiL | 89 | 45 | 20 | 25 | CL | 2.60 | -- | 136 | -- | -- | -- | -- | -- | -- | -- | -- |

(3 of 3 sheets)

THAILAND: SOILS OF THE CENTRAL VALLEY AND SOUTHEAST COAST

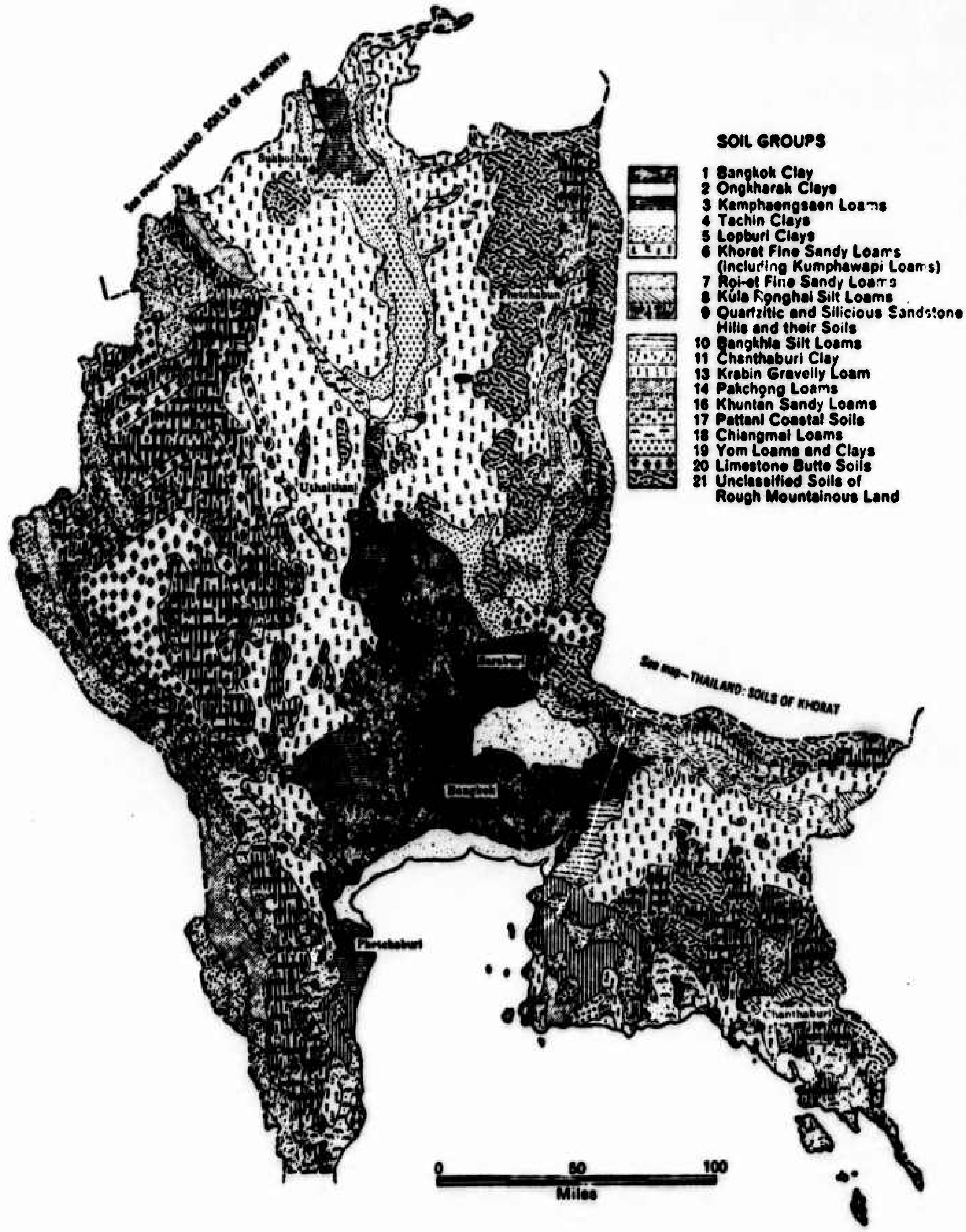



Fig. 2. Major soil groups--distribution of soils in the central valley and southeast coast (permission for reproduction granted by American Geographical Society, 20 May 1965)

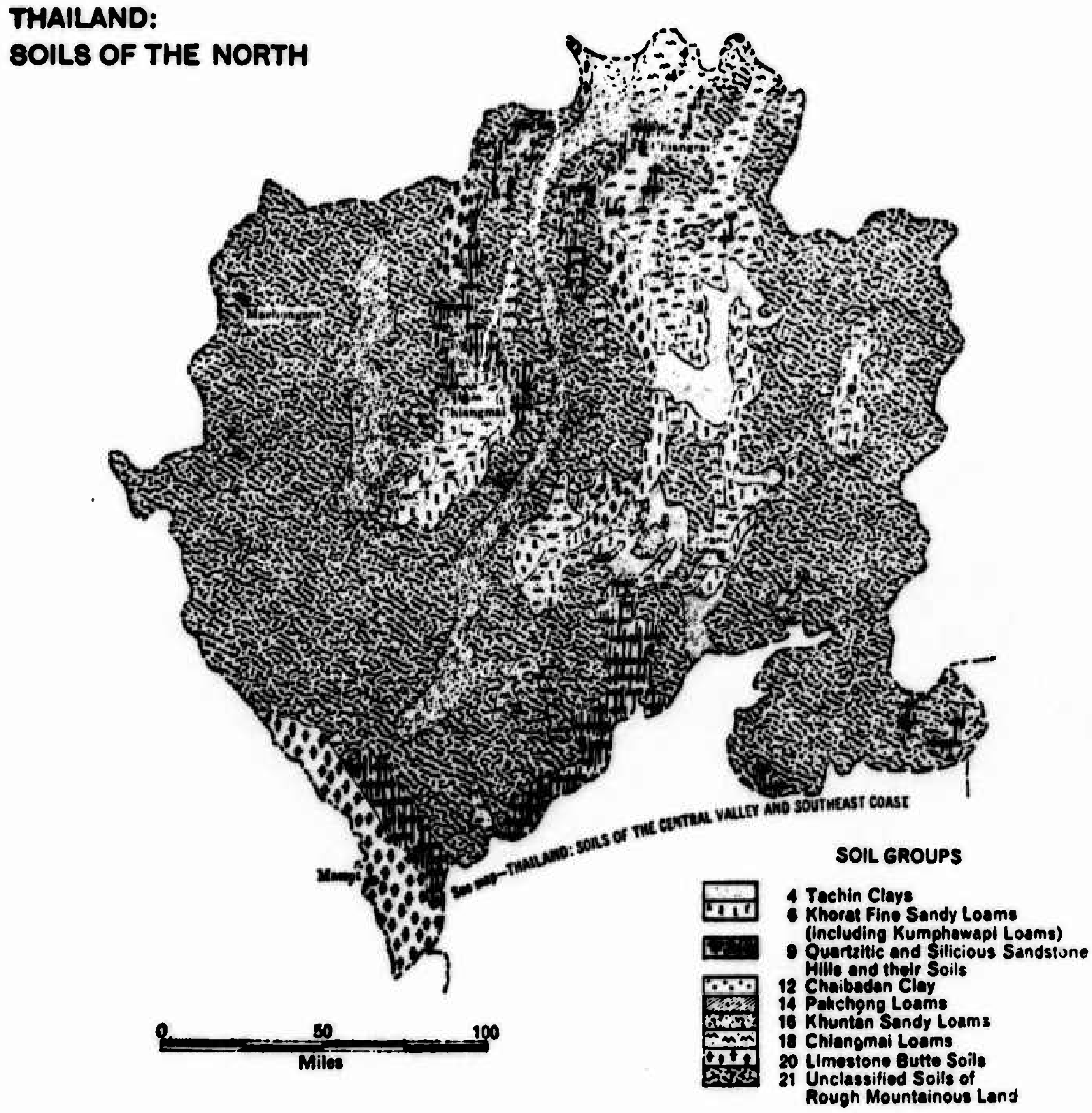



Fig. 3. Major soil groups--distribution of soils in northern Thailand (permission for reproduction granted by American Geographical Society, 20 May 1965)

THAILAND: SOILS OF KHORAT

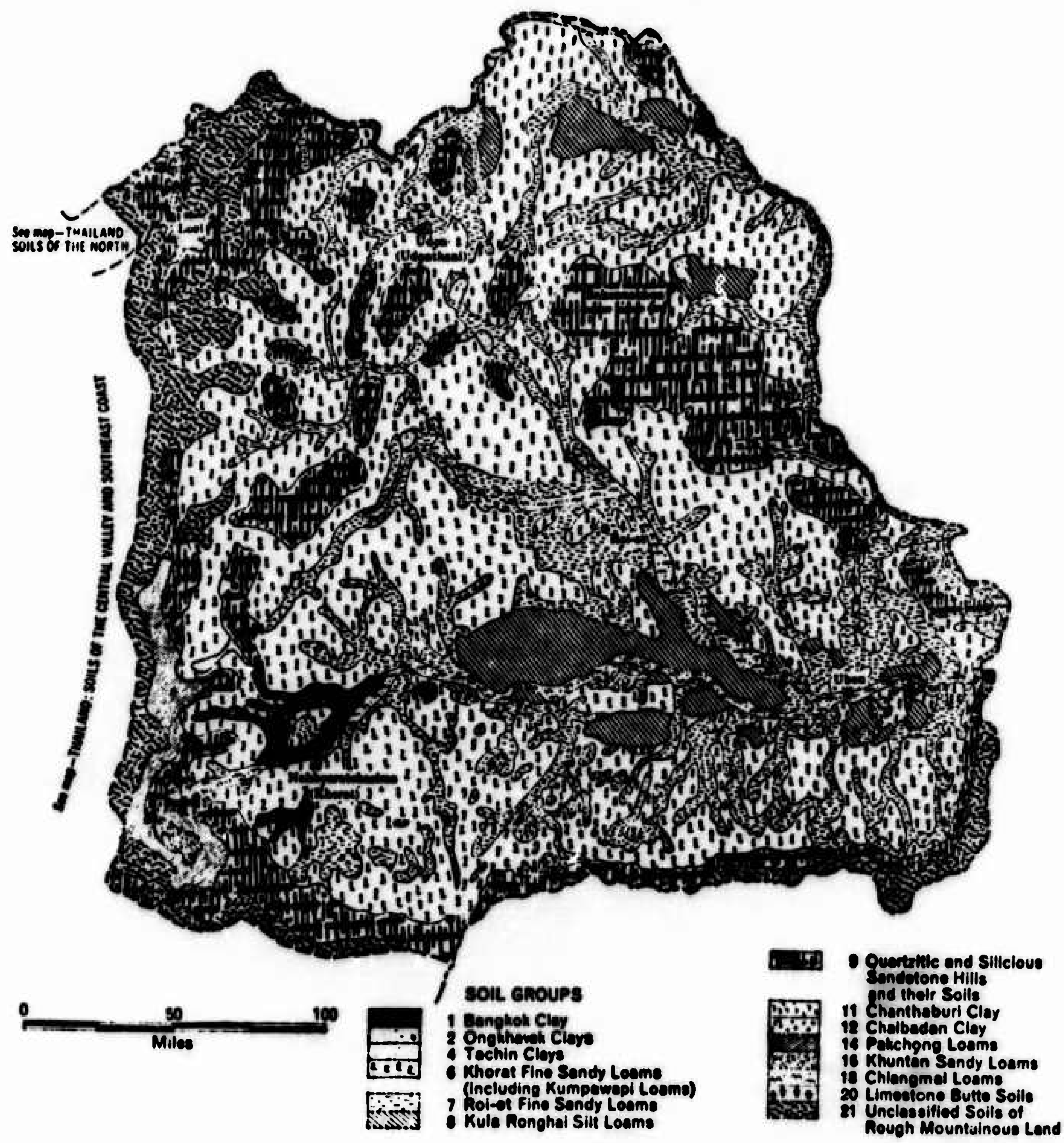



Fig. 4. Major soil groups--distribution of soils in Khorat (permission for reproduction granted by American Geographical Society, 20 May 1965)

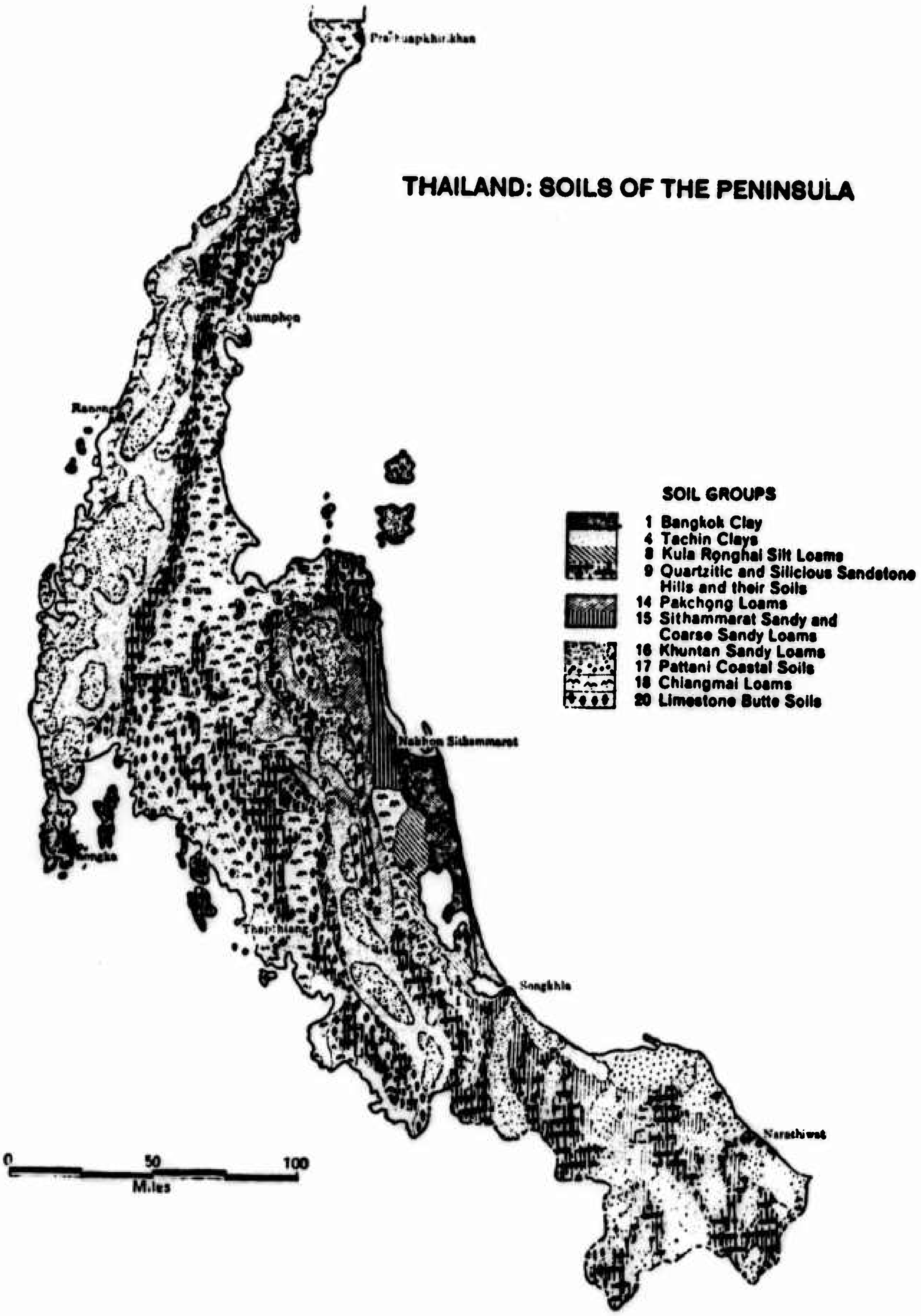



Fig. 5. Major soil groups--distribution of soils in the peninsula (permission for reproduction granted by American Geographical Society, 20 May 1965)


Fig. 6. Bangkok clay soils about 9 miles southeast of Ayutthaya in the Bangkok Plain. Note the dark centered sinkhole and the frequency of narrow surface drainage channels (January 1953)

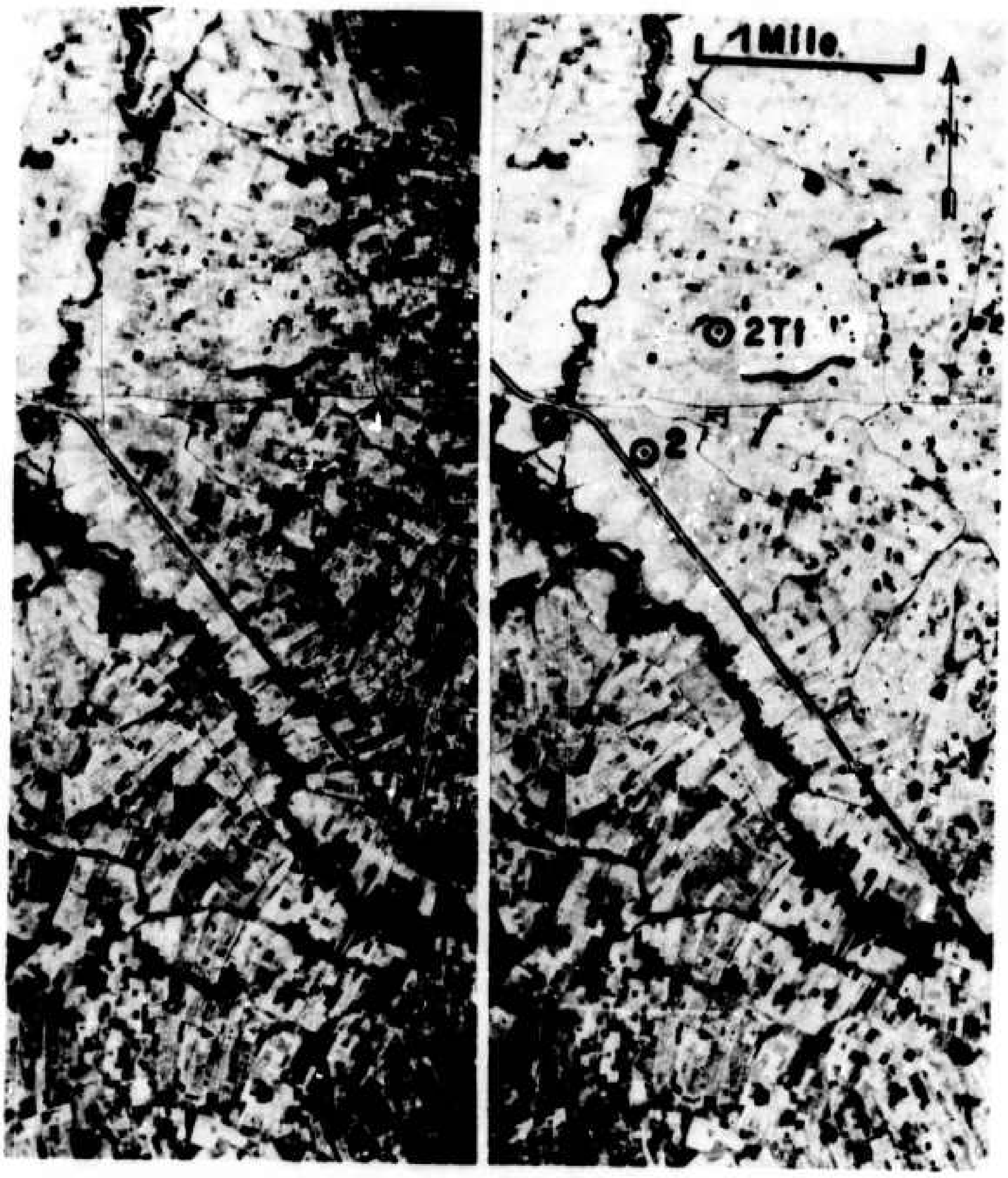



Fig. 7. Bangkok clay--stereopair of terrain in vicinity of two of the sample sites shown in fig. 6 (January 1953)


Fig. 8. Bangkok clay--typical ground photo showing level nature of Bangkok Plain. Water in foreground is in borrow pit adjacent to road. Area of dark-toned vegetation in middle ground is brush in sink-hole pond. Tree line in background borders a canal (4 September 1964)

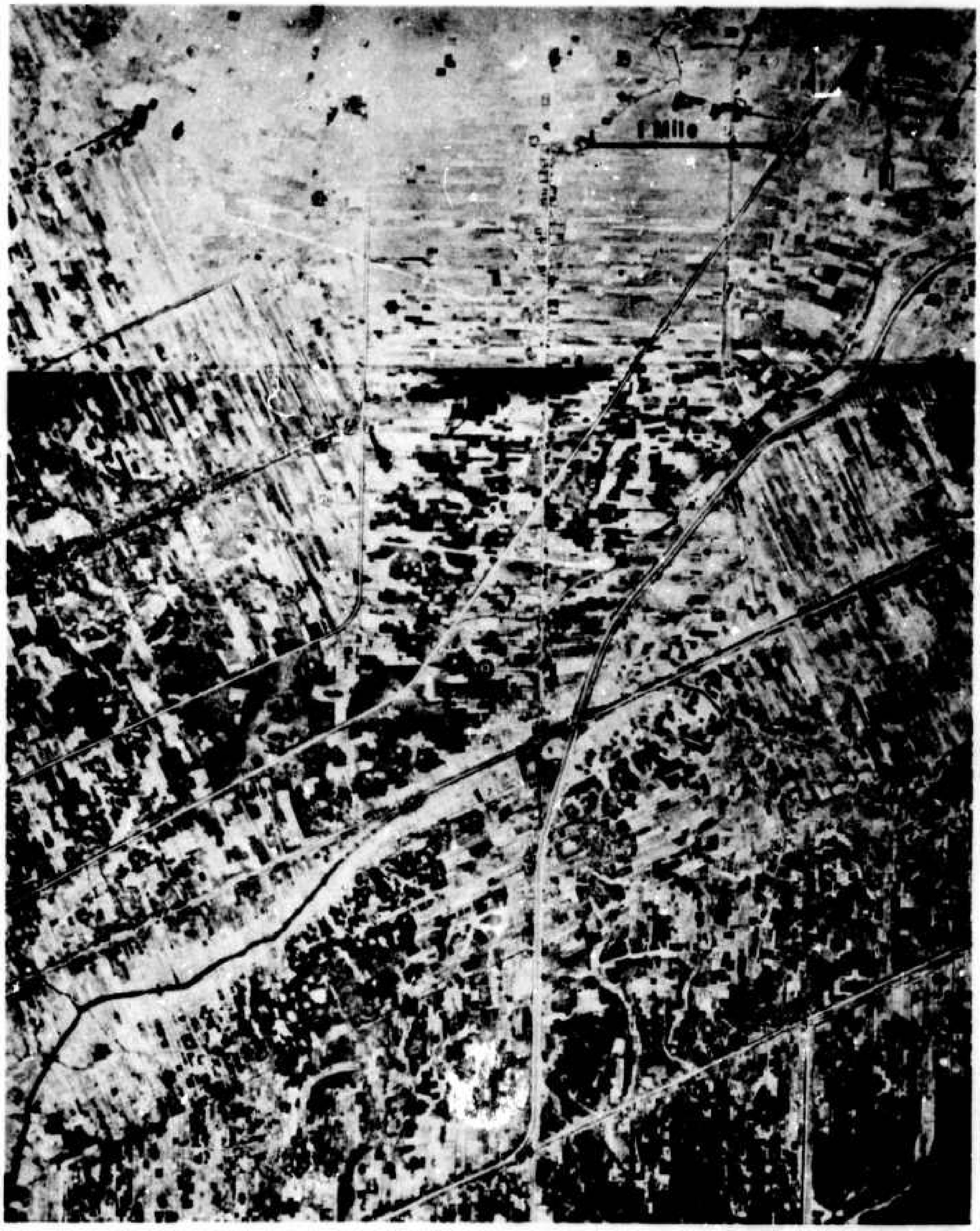



Fig. 9. Ongkharak clay soils about 15 miles southeast of Ayutthaya. Light tones occur in paddy areas adjacent to surface water, and dark tones in uncultivated areas (January 1953)

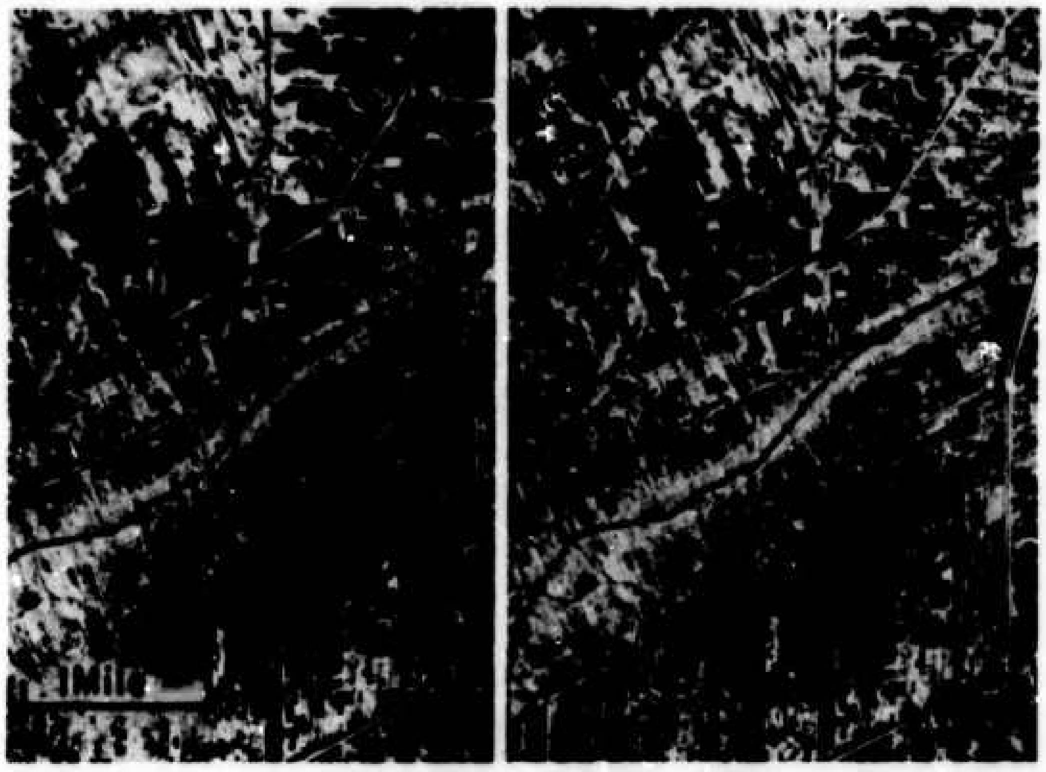



Fig. 10. Ongkharak clay--stereopair of area shown in fig. 9 (January 1953)

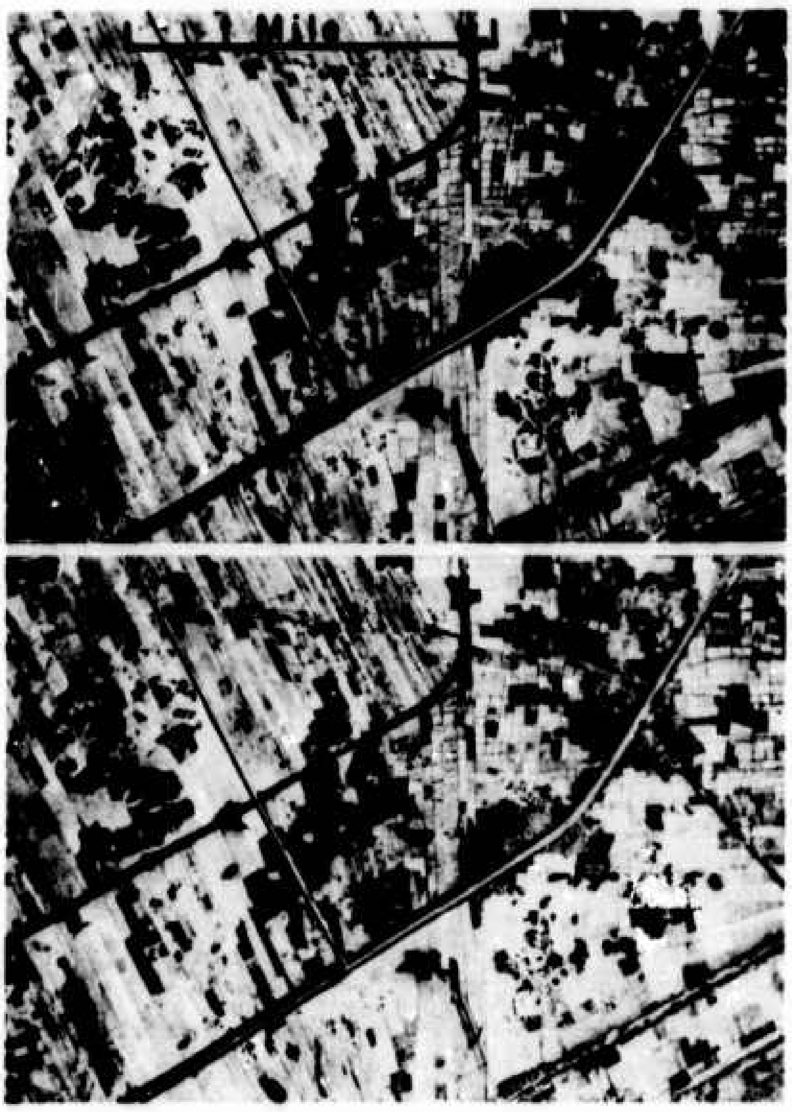



Fig. 11. Ongkharak clay--stereopair of area in fig. 10 as photographed 12 years later (December 1964)

Fig. 12. Ongkharak clay--view northeast from sample site 31 (15 September 1964)

Fig. 13. Ongkharak clay--view southeast from sample site 33 (16 September 1964)


Fig. 14. Tachin clay--saline clays in coastal mud flat areas directly south of Chanthaburi (February 1953)

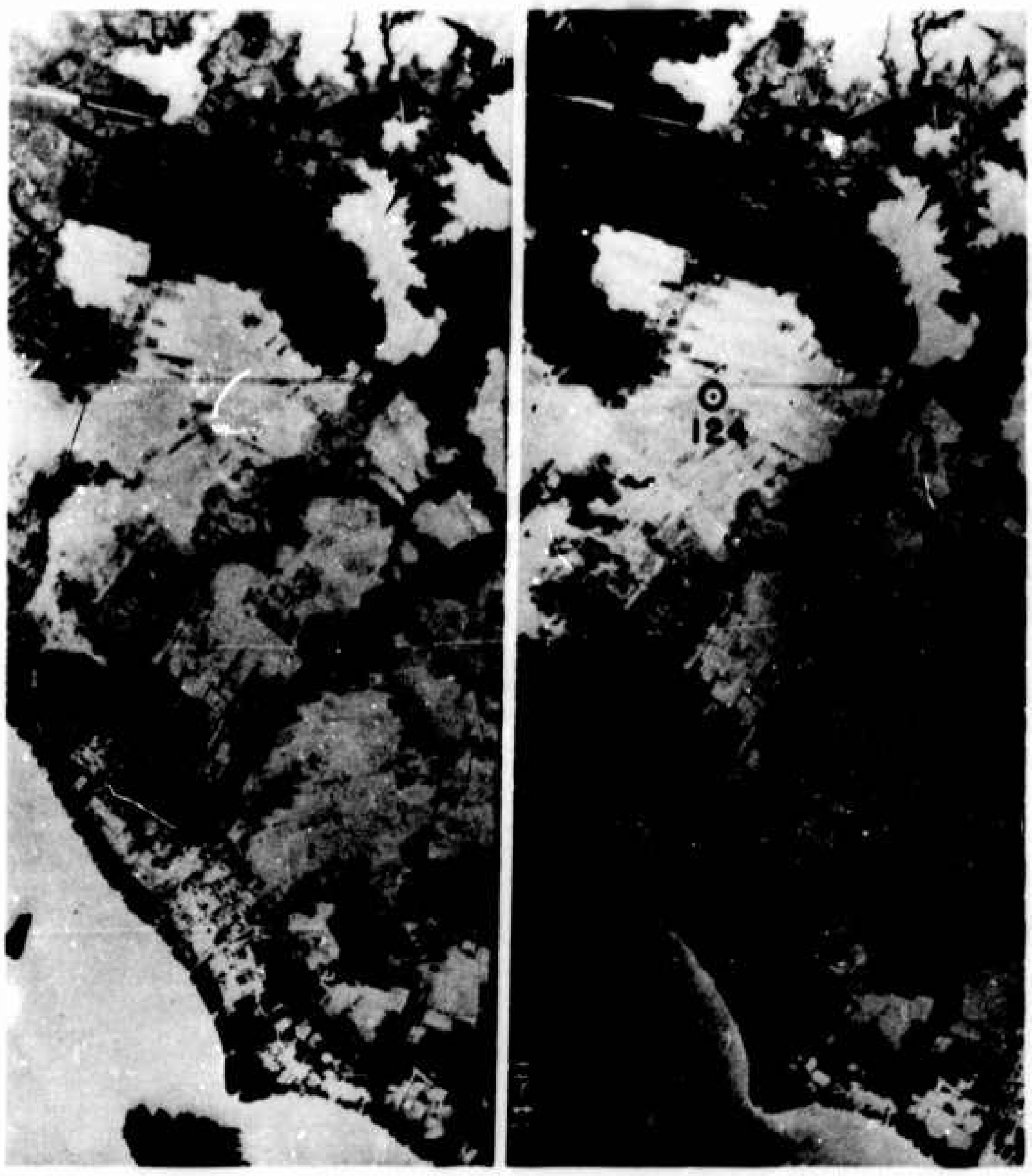




Fig. 15. Tachin clay--reclaimed coastal mud flat areas have light photo tones. Dark tones at top of illustration are areas of nipa palms within tidal range. Dark tones at bottom left are shrimp beds along coastline (February 1953)

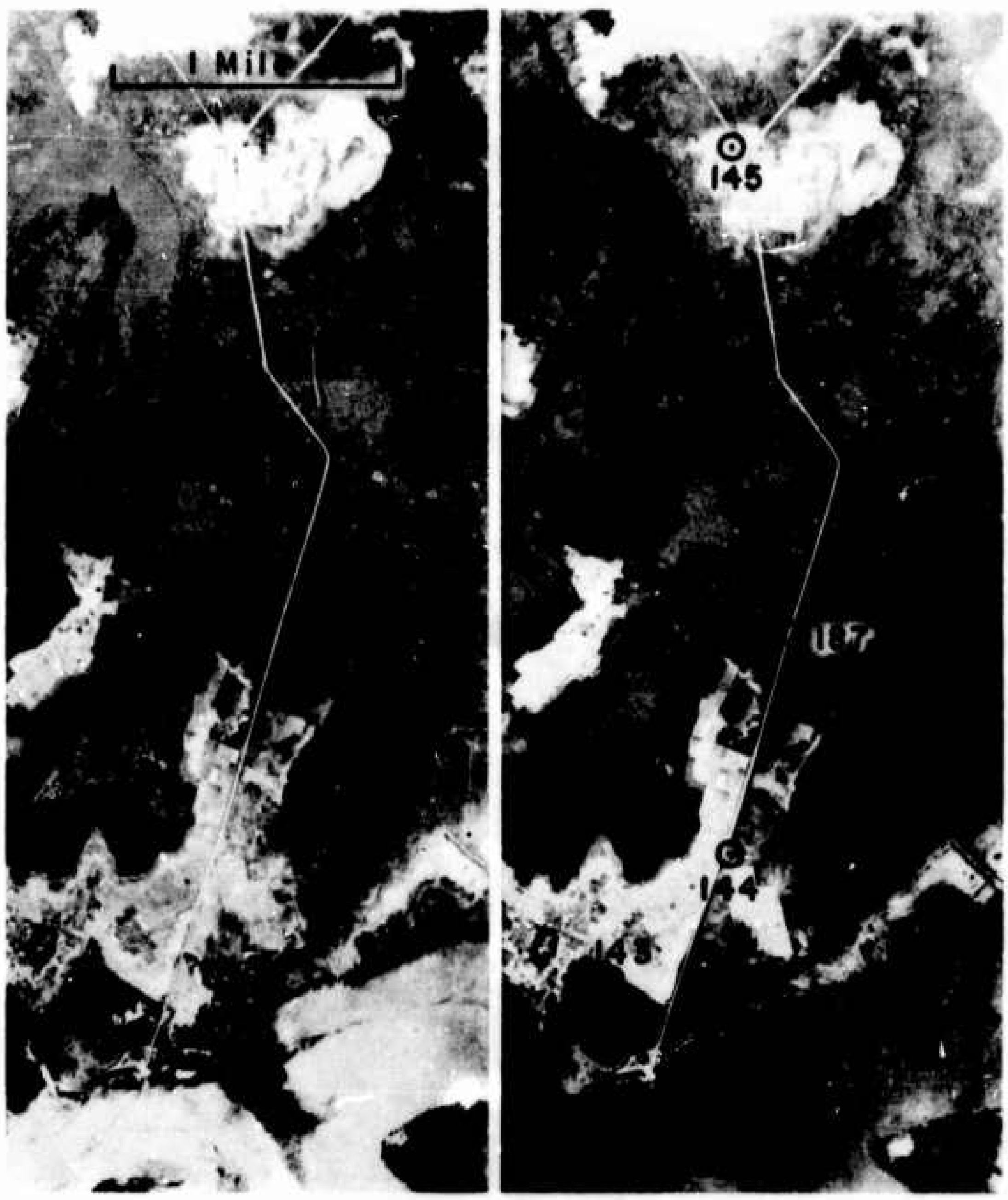



Fig. 16. Tachin clay--sample sites in saline clays of coastal mud flats (February 1953)

Fig. 17. Tachin clay--view, from the south, of sample site 124 in cultivated mud flats (8 October 1964)

Fig. 18. Tachin clay--view, from the northeast, of site 127. Newly reclaimed field to right and nipa palms along rear edge of field (9 October 1964)

Fig. 19. Tachin clay--view, from the south, of sample site 144. Level reclaimed mud flats with nipa and mangrove vegetation along coast in background (11 October 1964)

Fig. 20. Tachin clay--dry clay skins and surface shrinkage cracks at sample site 144 (11 October 1964)


Fig. 21. Lop Buri clay--dark karst area of Lop Buri residual and sinkhole colluvial clays about 15 miles southeast of Lop Buri. Light-toned soils around perimeter of karst area are Lop Buri alluvial apron clays (February 1953)

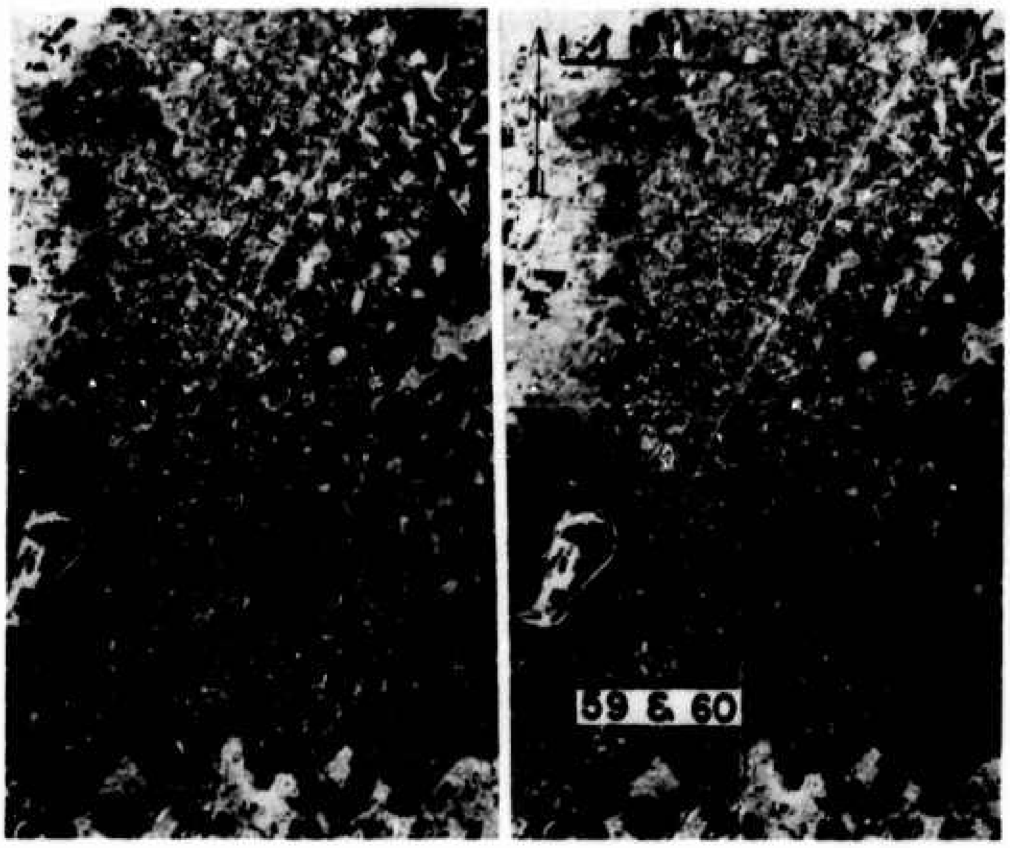



Fig. 22. Lop Buri clay--stereopair of karst topography in the vicinity of sample sites 59 and 60. Note trees only on ridges and only rice grown in sinkholes (February 1953)

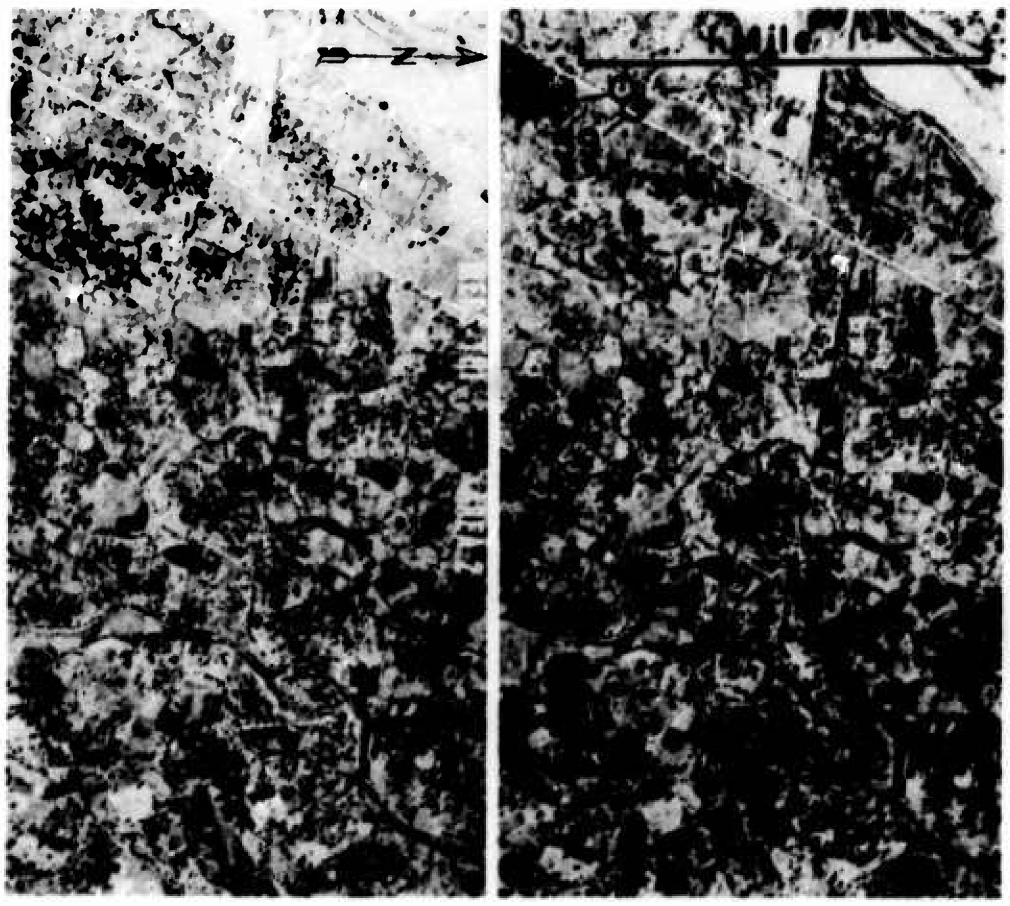


Fig. 23. Lop Buri clay--same area as fig. 22, 12 years later. Note the connected sinkholes (December 1964)

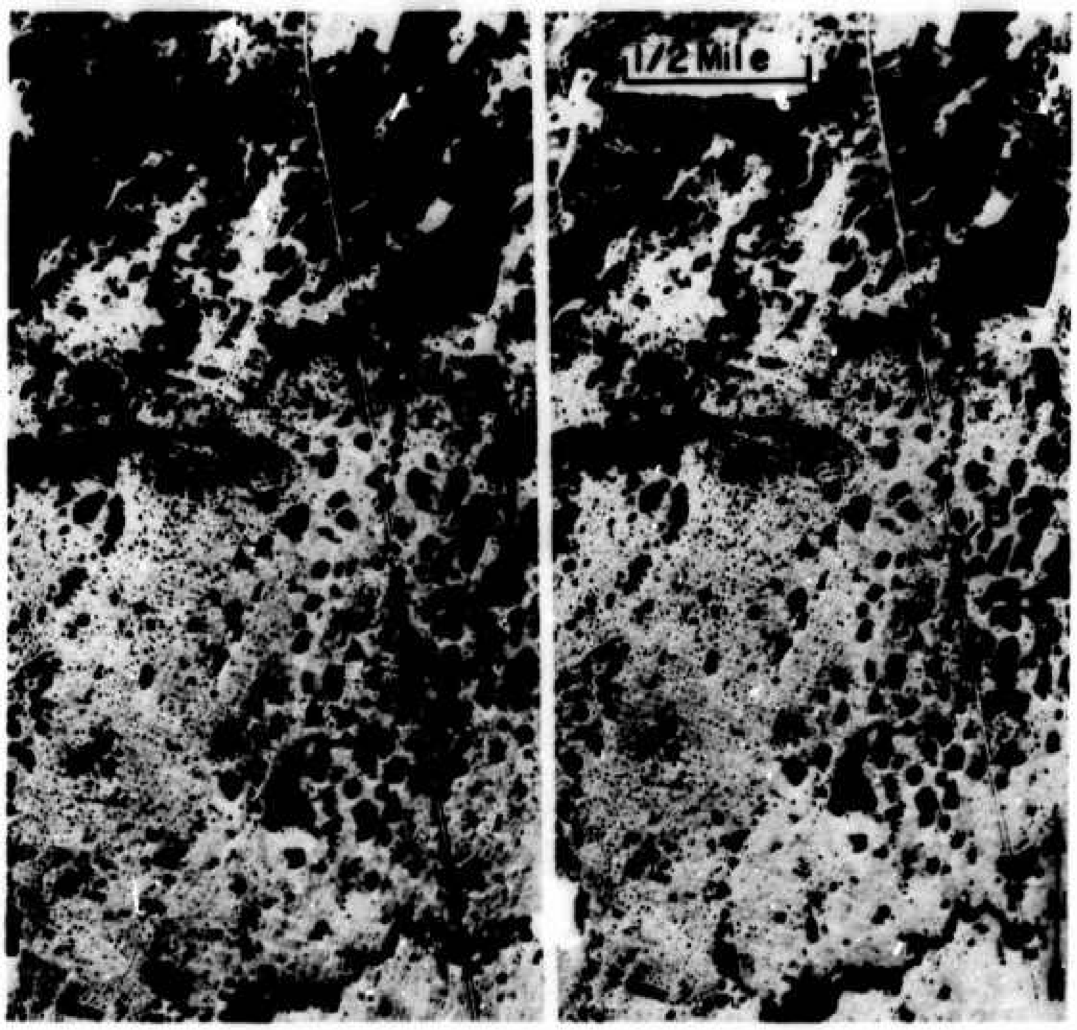



Fig. 24. Lop Buri clay--small islands of residual clay surrounded by alluvial apron clays (February 1953)

Fig. 25. Lop Buri clay--exposed soils in drainage ditch of borrow pit near sample sites 59 and 60. Black soils are sinkhole channel clays; white material is cemented limestone concretions or parent material (19 September 1964)

Fig. 26. Lop Buri clay--sample site 59 in sinkhole (low area in foreground); sample site 60 on low rise in background (19 September 1964)

Fig. 27. Lop Buri clay--view from direction A in fig. 24. Note white limestone gravels on surface of residual island soils. Colluvial soils planted in rice to the rear (14 September 1964)

Fig. 28. Lop Buri clay--view from direction B in fig. 24. Tree-covered islands of residual soils in background; colluvial low in foreground (14 September 1964)

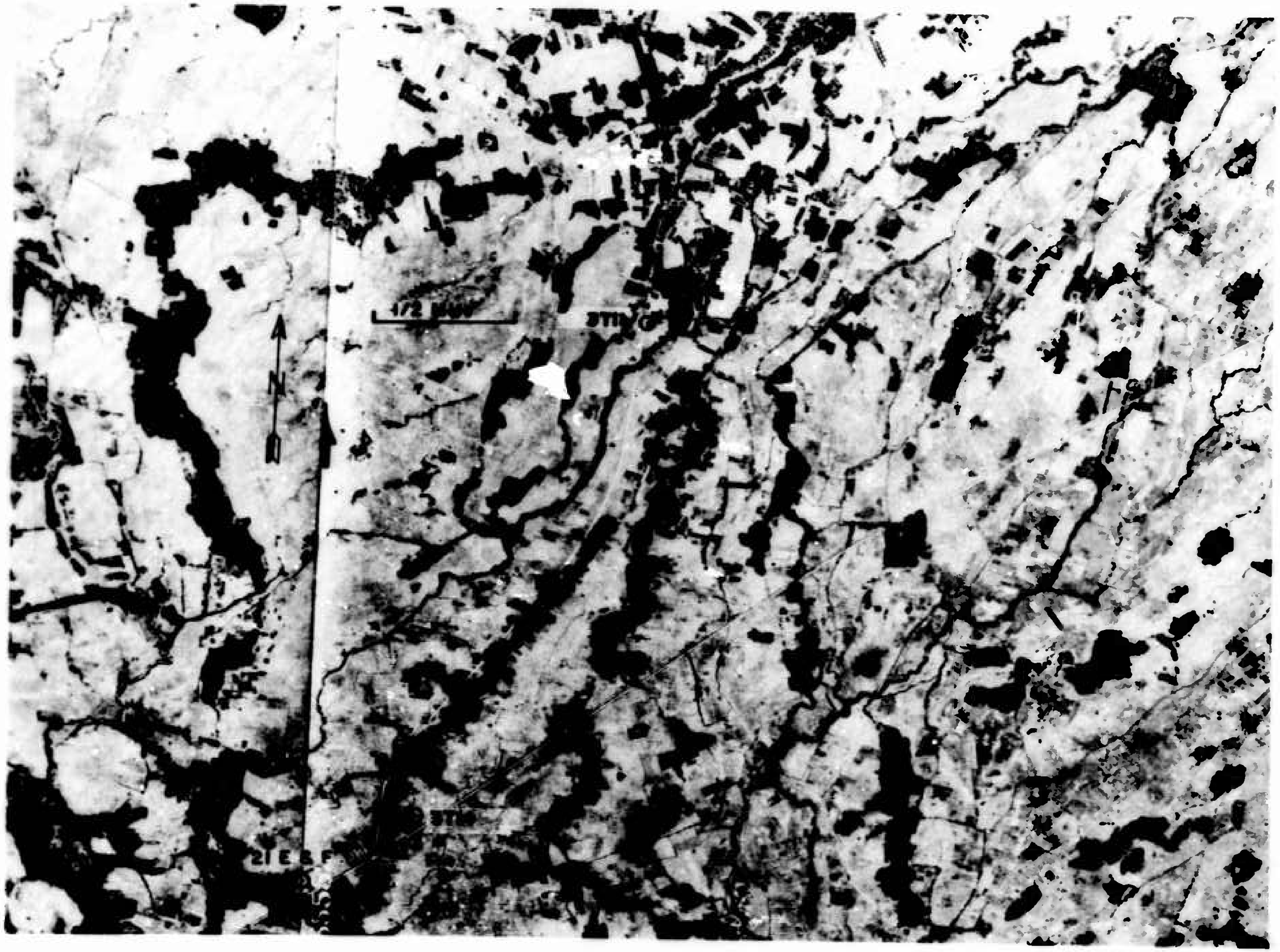



Fig. 29. Chiang Mai loam in alluvial apron 2.5 miles northeast of Chiang Mai (January 1954)

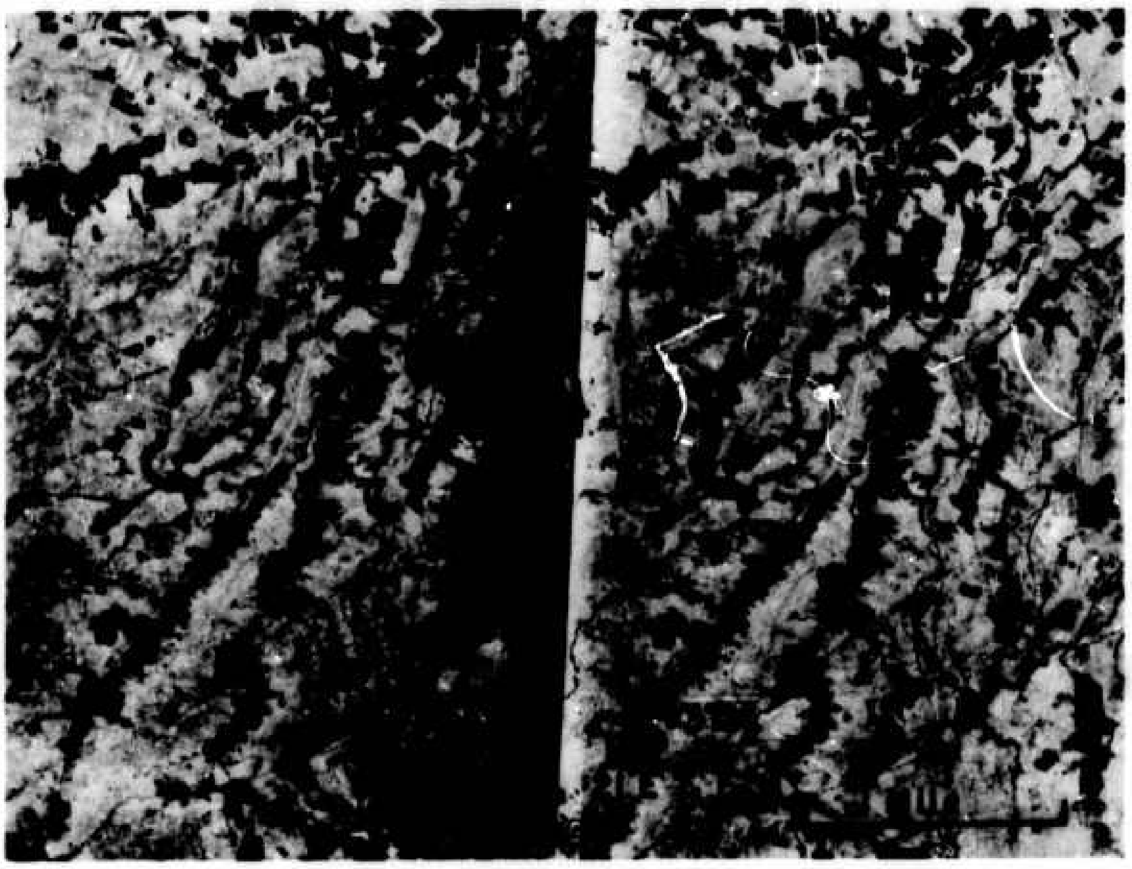


Fig. 30. Chiang Mai loam--stereopair of area shown in fig. 29. Linear vegetated areas follow ridge lines; low areas are farmed in rice (January 1954)

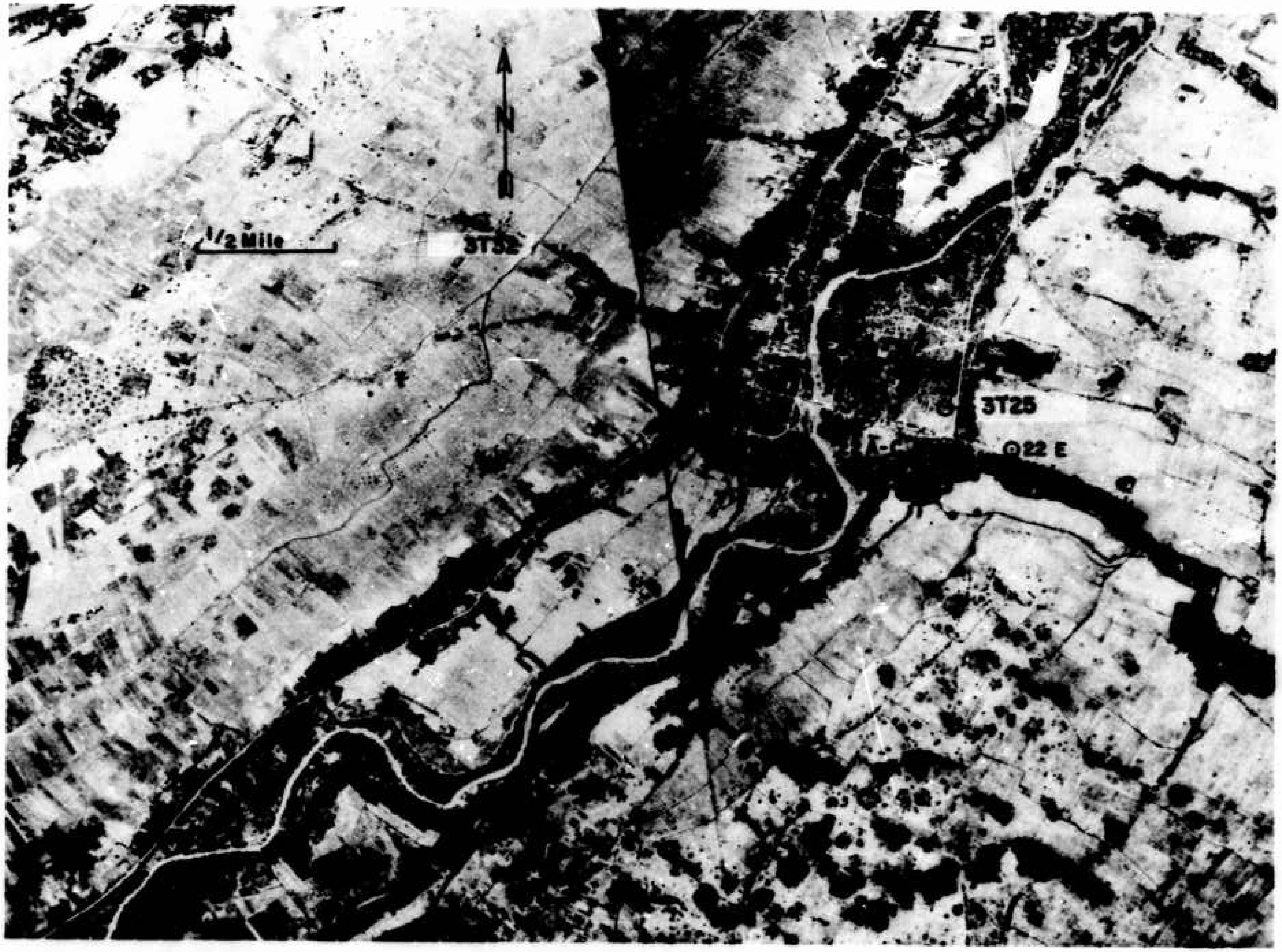



Fig. 31. Chiang Mai loam along Nam Mae Kuang at Lamphun, about 13 miles south of Chiang Mai (January 1954)

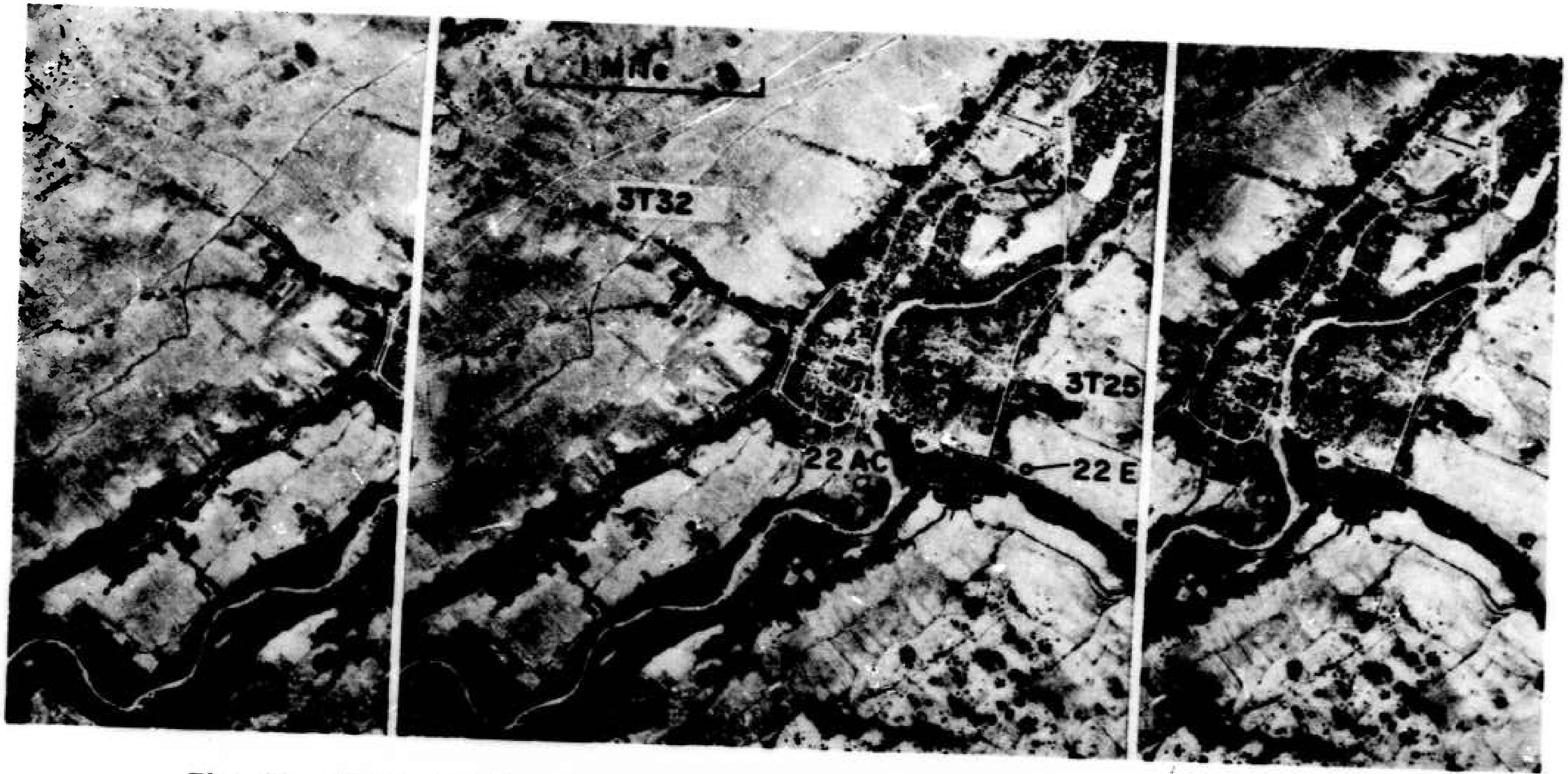



Fig. 32. Chiang Mai loam--stereotriplet of area shown in fig. 31 (January 1954)


Fig. 33. Chanthaburi clay soils about 7 miles east and northeast of Chanthaburi (February 1953)

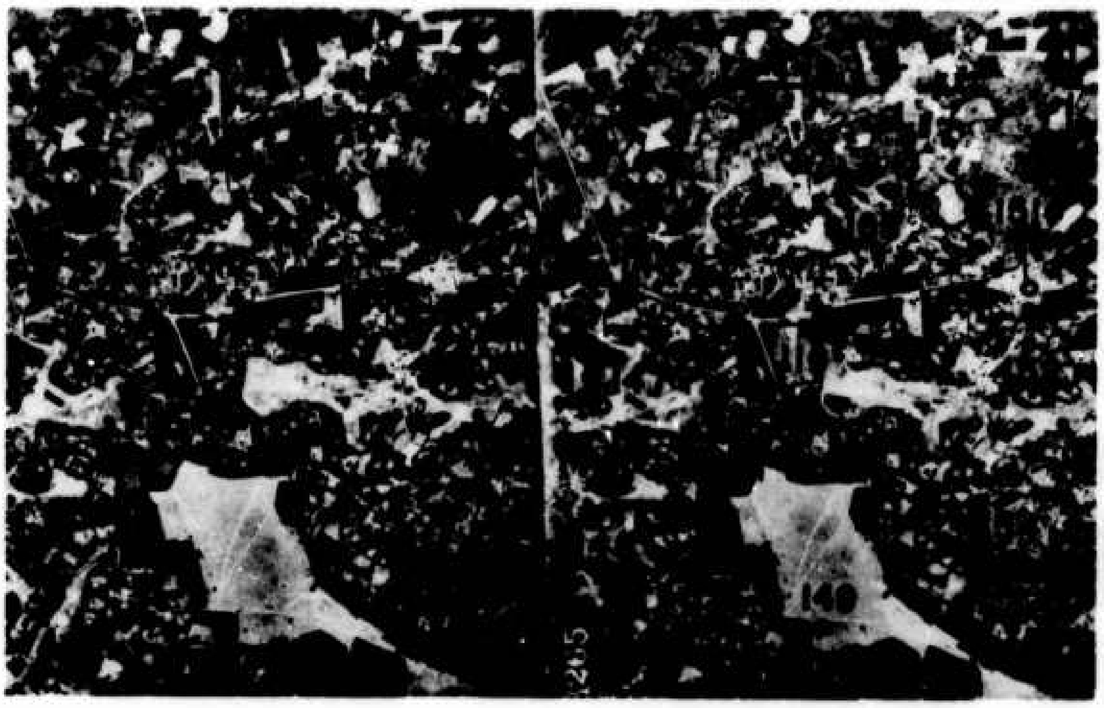



Fig. 34. Chanthaburi clay--stereopair of area in fig. 33
(February 1953)

Fig. 35. Chanthaburi clay--view north over local airfield near site 149 showing even surface of a large, shallow, sloping ridge (11 October 1964)

Fig. 36. Chanthaburi clay--exposed profile in Chanthaburi clay shows uniform tones and texture and crumb structure of soils (11 October 1964)

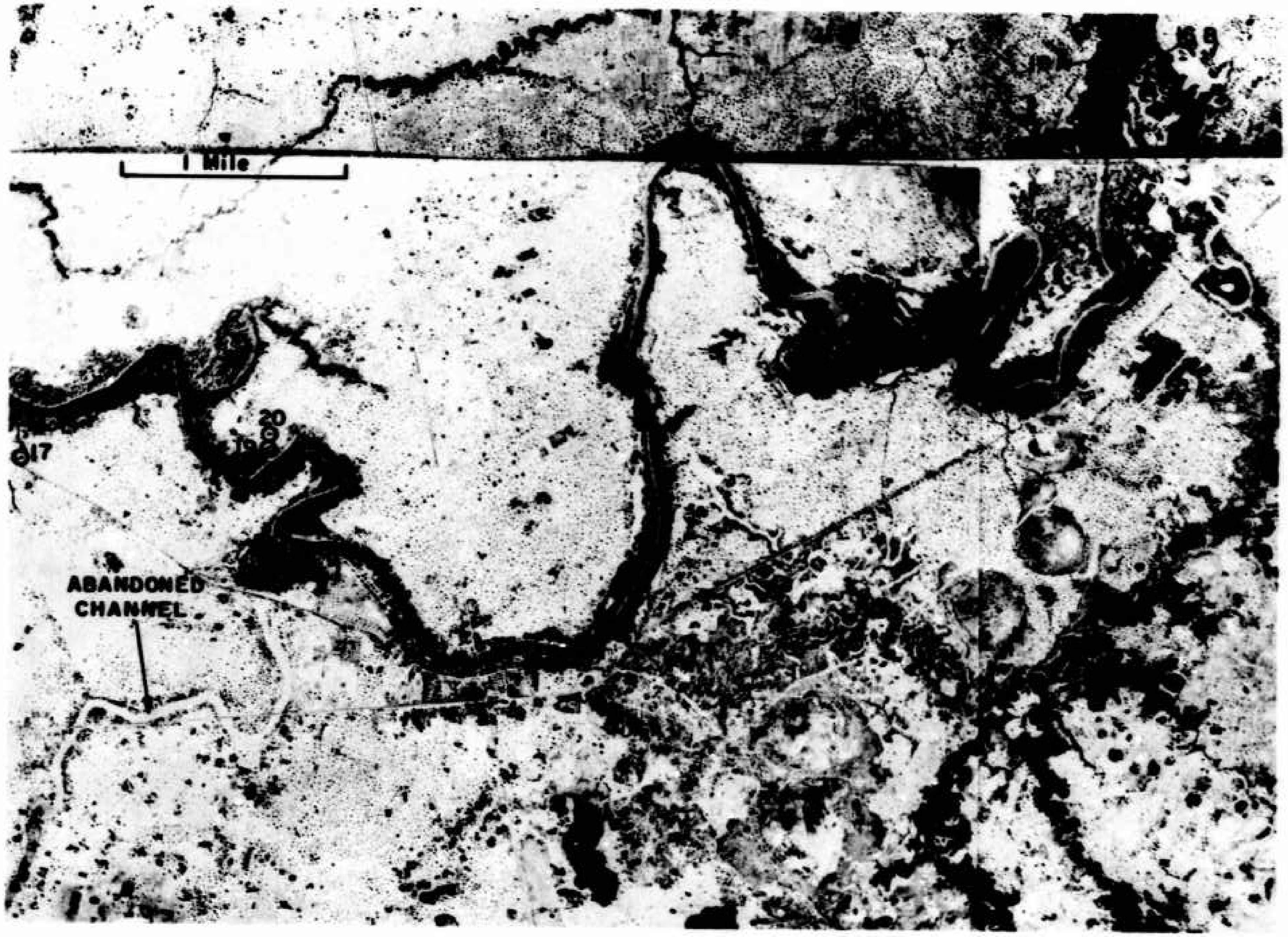



Fig. 37. Natural levee soils bordering Maenam Pa Sak at Sara Buri (February 1953)

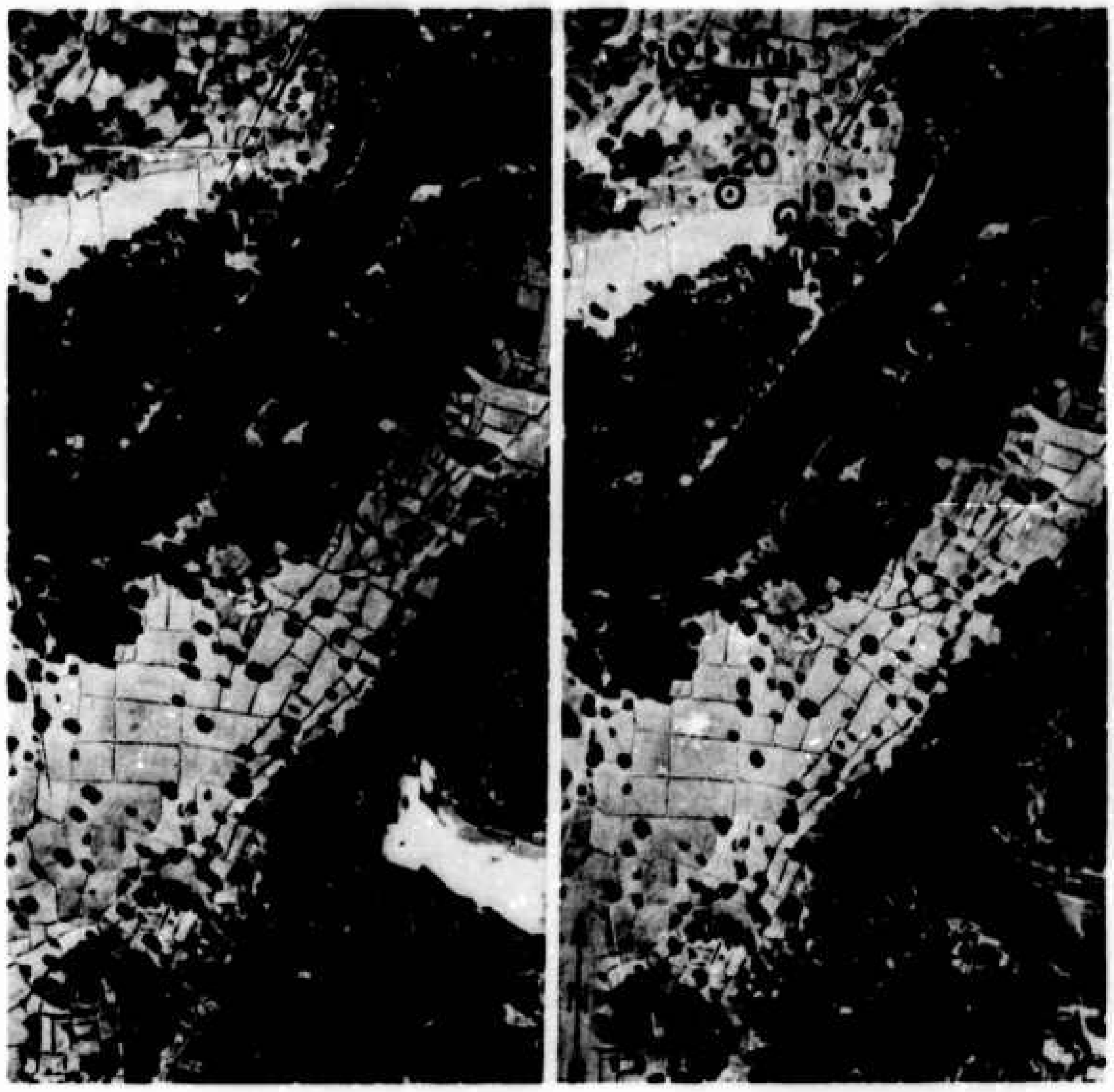



Fig. 38. Natural levee--large-scale stereopair showing sample sites on terrace and levee soils (December 1964)

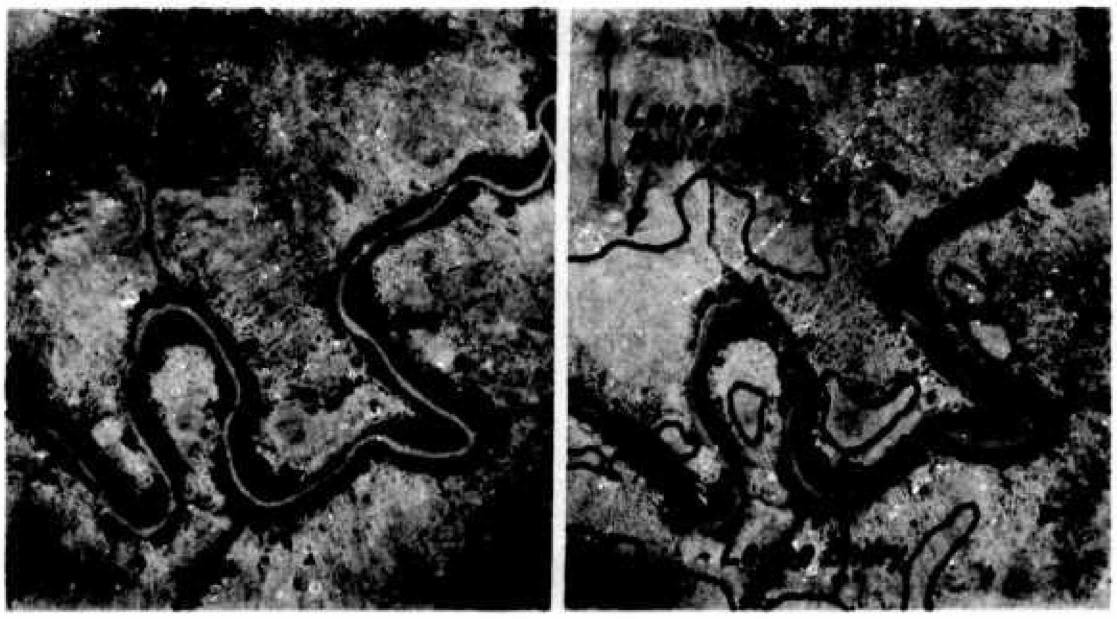


Fig. 39. Natural levee--small-scale stereopair showing termite mounds on levee soils (February 1953)

Fig. 40. Natural levee--view west over sample site 19.
Note lack of termite mounds (14 September 1964)

Fig. 41. Natural levee--view north from sample site 20.
Note termite mounds with trees (14 September 1964)

Fig. 42. Natural levee--view north over sample site 17. Trees in background line the riverbank (8 September 1964)


Fig. 43. Beach ridges along shoreline and inland south of Chanthaburi (February 1953)

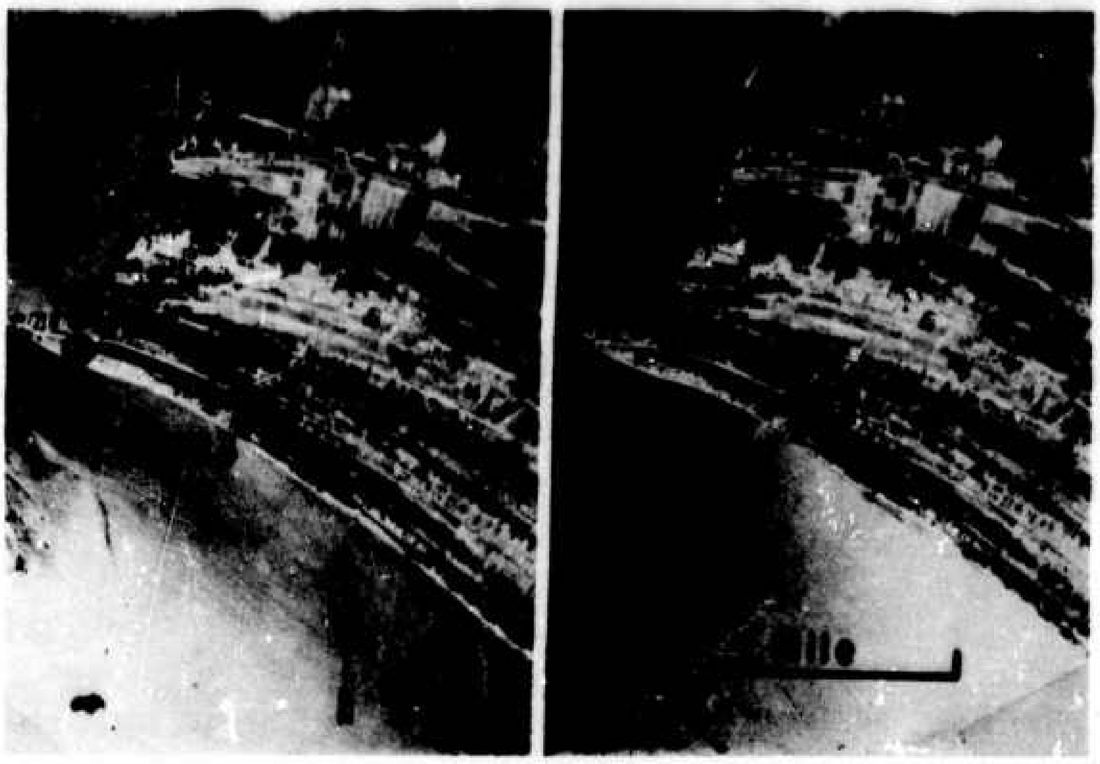


Fig. 44. Beach ridges in coastal area
(February 1953)

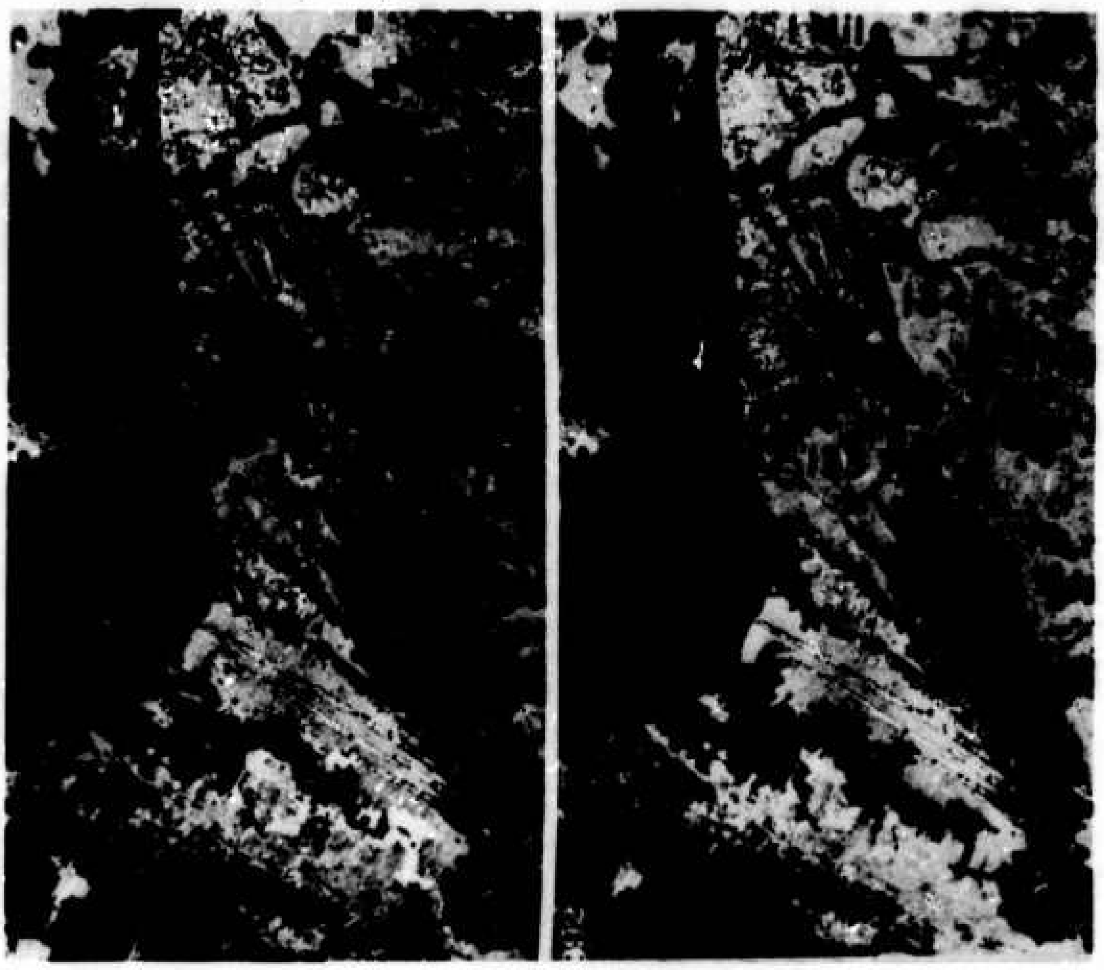


Fig. 45. Beach ridges somewhat removed from shoreline
(February 1953)

Fig. 46. Beach ridge--view east along coastal sand beach from sample site 122 (8 October 1964)

Fig. 47. Beach ridge--view east over sample site 134. Note white sand surface soils (10 October 1964)

Fig. 48. Beach ridge--typical roadway on unstabilized sand beach ridge (9 October 1964)


Fig. 49. Abandoned river channel (January 1953)

Fig. 50. Abandoned channel--same area as fig. 49, 12 years later (December 1964)

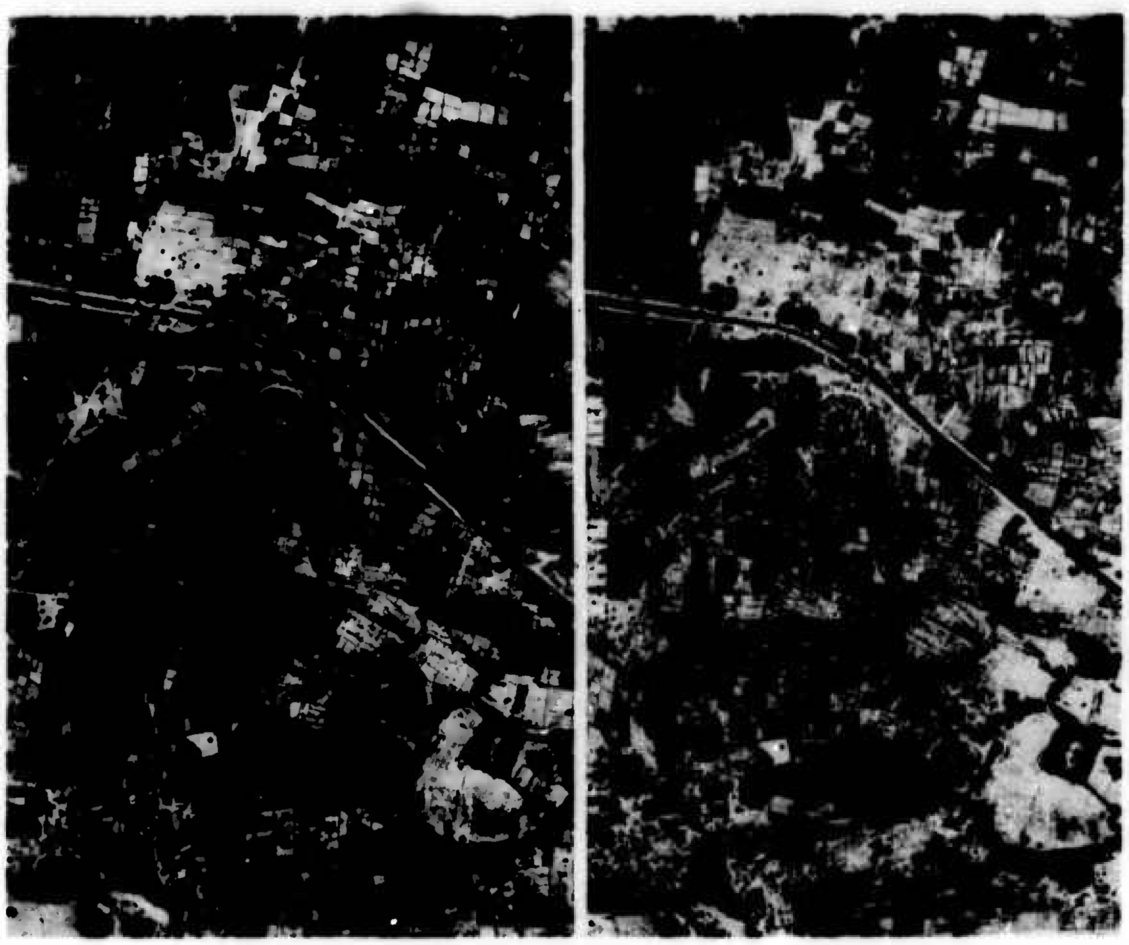


Fig. 51. Abandoned channel--stereopair of area in fig. 50 showing sample sites in abandoned river channel (December 1964)

Fig. 52. Abandoned channel--view west toward sample site 2T15 (16 September 1964)

Fig. 53. Abandoned channel--view north over sample site 12D (16 September 1964)

# SURFACE GEOMETRY

Table 3

Surface Geometry

Summary of Data

| Feature | Site | Location: Map Sheet* | Location: Grid Coordinates | Date of Sample | Illustrations of Dikes, Fig.: Plan | Illustrations of Dikes, Fig.: Cross Section | Photo Illustrations, Fig.: Air Photo | Photo Illustrations, Fig.: Ground Photo |
|---|---|---|---|---|---|---|---|---|
| Terraced paddies | | | | | | | | |
| In narrow mountain valleys | SG-9 | 5154II | 111980 | 9-4-64 | 55 | -- | 54, 55 | 56, 57 |
| On local transition slopes | SG-65 | 5154II | 072926 | 9-17-64 | 59 | 59 | 58, 59 | 60 |
| On regional slopes | SG-81 | 5154I | 043158 | 9-19-64 | 65 | 65 | 61, 62 | 63, 64 |
| On side slopes of abandoned stream channels | SG-117 | 5154I | 907098 | 9-27-64 | -- | -- | 66, 67, 68 | 70, 71 |
| On stream valley sides in flat areas | SG-105 | 5154II | 025876 | 9-25-64 | 76 | 76 | 72, 73 | 74, 75 |
| On natural levees | SG-41 | 4867III | 046808 | 9-10-64 | -- | -- | 79 | 79 |
| | SG-115 | 5154I | 956097 | 9-27-64 | 82 | 82 | 77, 78 | 80 |
| | SG-116 | 5154I | 933097 | 9-27-64 | 83 | 83 | 77 | 81 |
| Paddies with random arrangement | | | | | | | | |
| On slightly undulating terrain | SG-114 | 5154I | 002091 | 9-27-64 | 87 | 87 | 84, 85 | 86 |
| On flat terrain | SG-60 | 5154II | 084879 | 9-17-64 | 92 | 92 | 88, 89, 90 | 88, 91 |
| Boundary dikes on tidal flats | SG-163 | 5448III | 892797 | 10-16-64 | 99 | 99 | 98, 99 | 99 |
| Mountain valleys | SG-8 | 5154II | 119966 | 9-4-64 | -- | -- | 100, 101 | 100, 102, 103 |
| Rolling karst terrain | SG-26 | 5155II | 915240 | 9-6-64 | -- | -- | 104, 106 | 110 |
| | SG-28 | 5155II | 918273 | 9-6-64 | -- | -- | 104, 105 | 108 |
| | SG-73 | 5155II | 913229 | 9-19-64 | -- | -- | 104, 106 | 109 |
| | SG-124 | 5155II | 956276 | 9-29-64 | -- | -- | 104, 107 | 111 |
| Termite mounds | SG-19 | 5154I | 118092 | 9-5-64 | -- | -- | 112, 116 | 116 |
| | SG-47 | 5154I | 931118 | 9-16-64 | -- | -- | 112, 117 | 117 |
| | SG-50 | 5154I | 017132 | 9-16-64 | -- | -- | 112, 118 | 118 |
| | SG-51 | 5154I | 053116 | 9-16-64 | -- | -- | 112, 114 | 120 |
| | SG-52 | 5154I | 055106 | 9-16-64 | -- | -- | 112, 114 | 119 |

* Army Map Service, L708, 1:50,000.

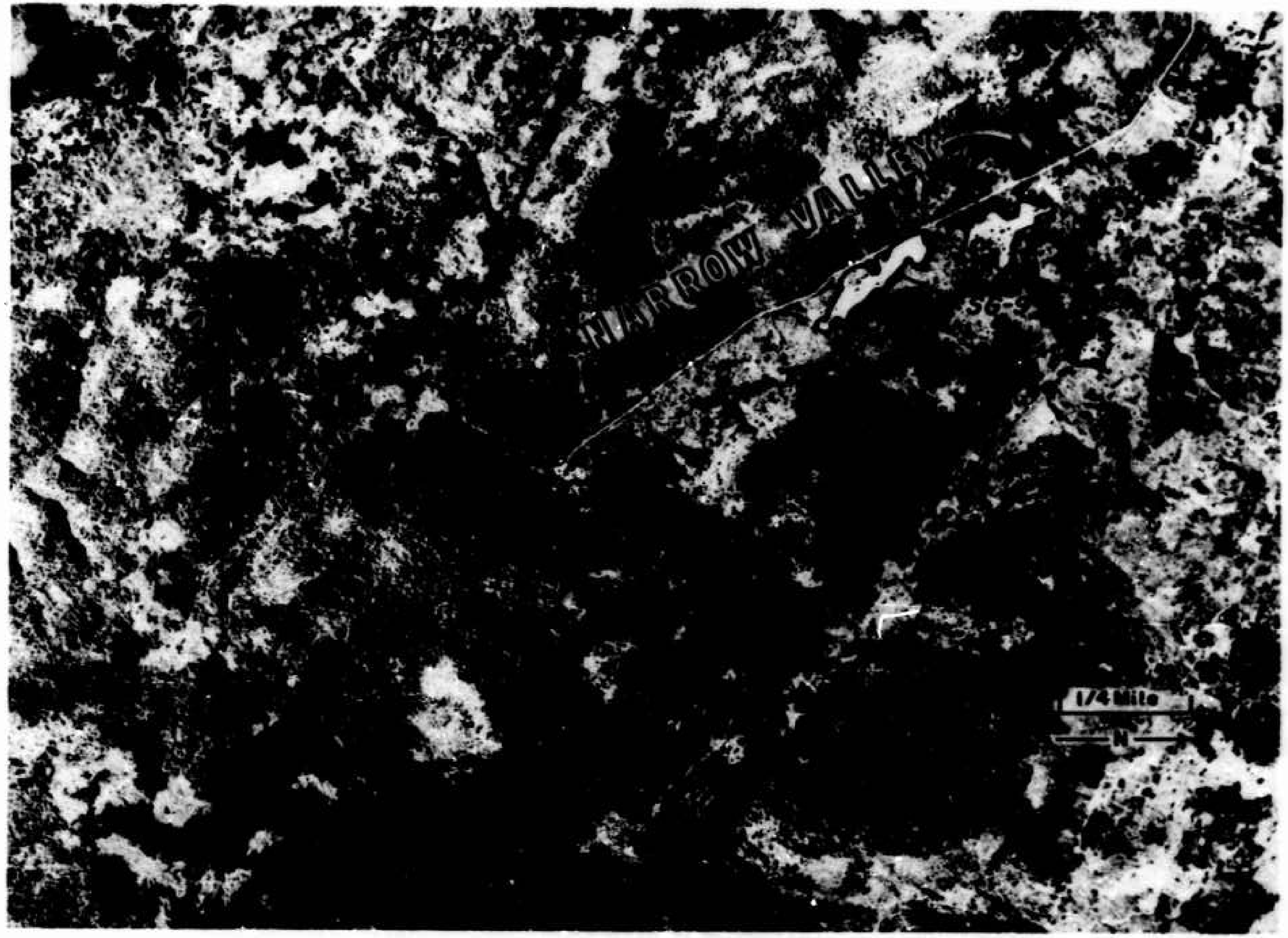



Fig. 54. Terraced paddies in narrow valley in low mountains, site SG-9 (January 1965)

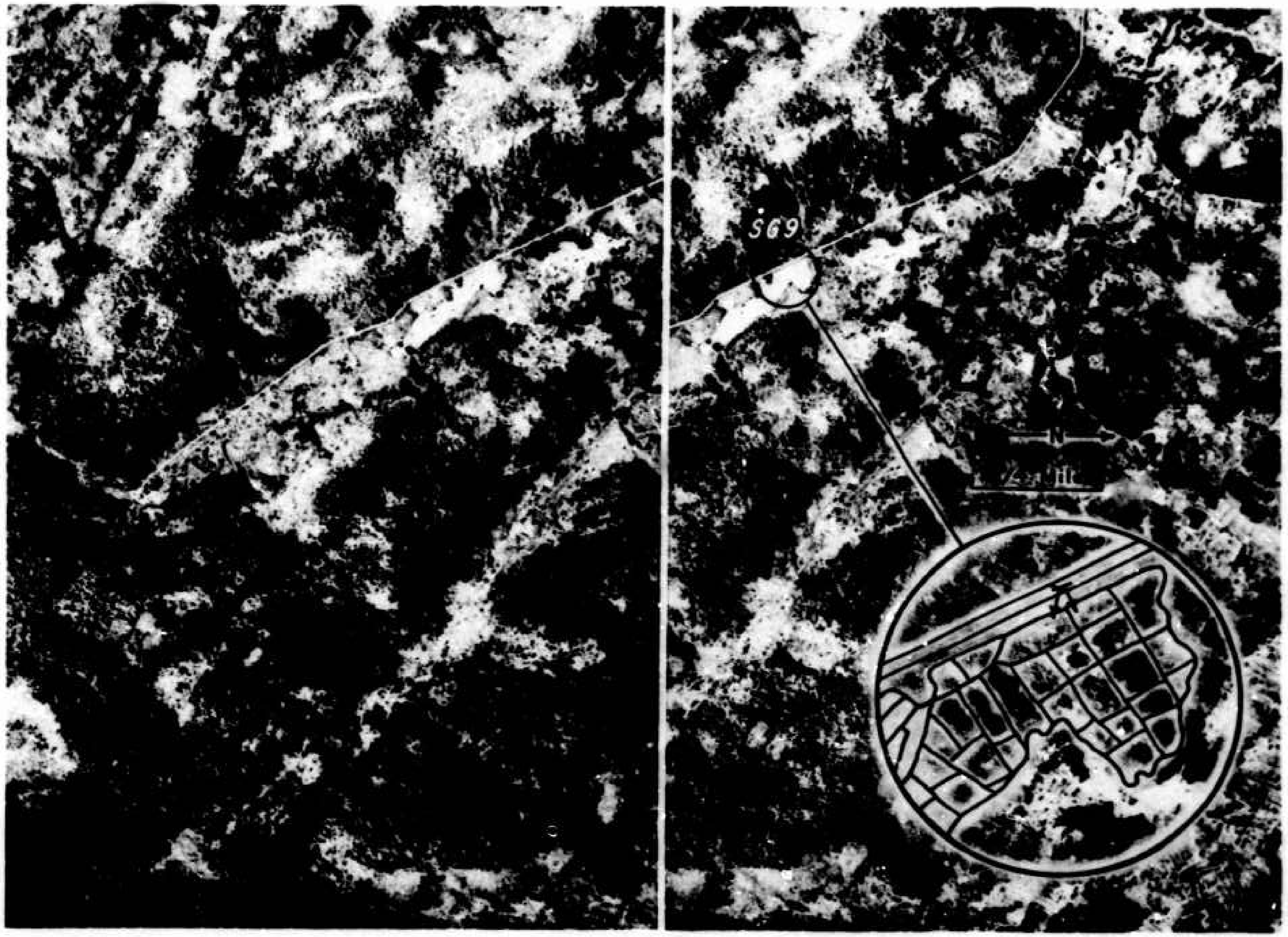



Fig. 55. Terraced paddies--plan of paddies in narrow valley. Arrows in inset show direction of ground photos shown in figs. 56 and 57 (January 1965)

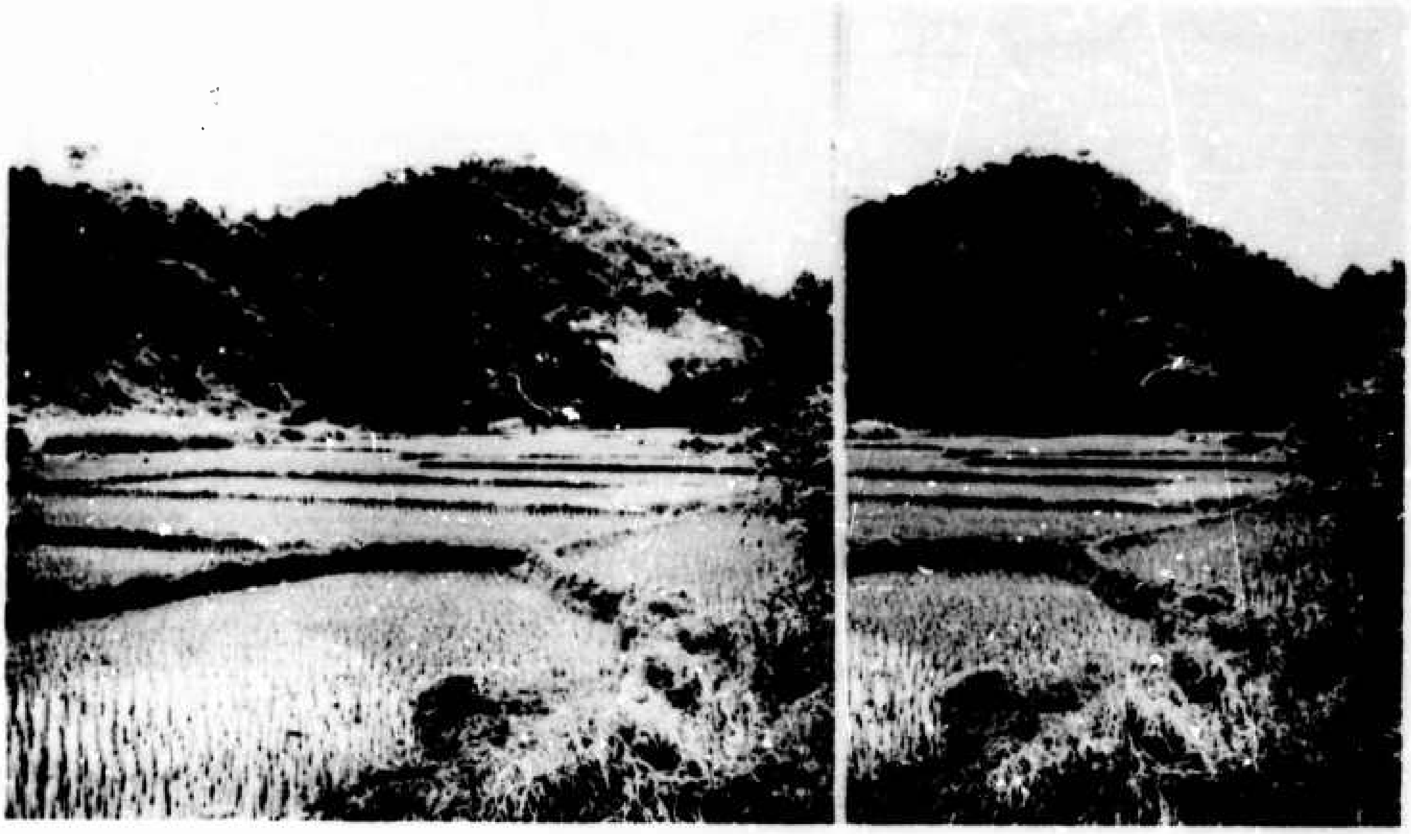


Fig. 56. Terraced paddies--terracing up valley to east-southeast, site SG-9 (September 1964)

Fig. 57. Terraced paddies--terracing across valley to east, site SG-9 (September 1964)


Fig. 58. Terraced paddies on a local transition slope, site SG-65 (January 1965)


Fig. 59. Terraced paddies--stereopair, dike plan, and cross sections at site SG-65. Arrow shows direction of ground view shown in fig. 60 (air photo taken February 1965; cross sections taken 17 September 1964)

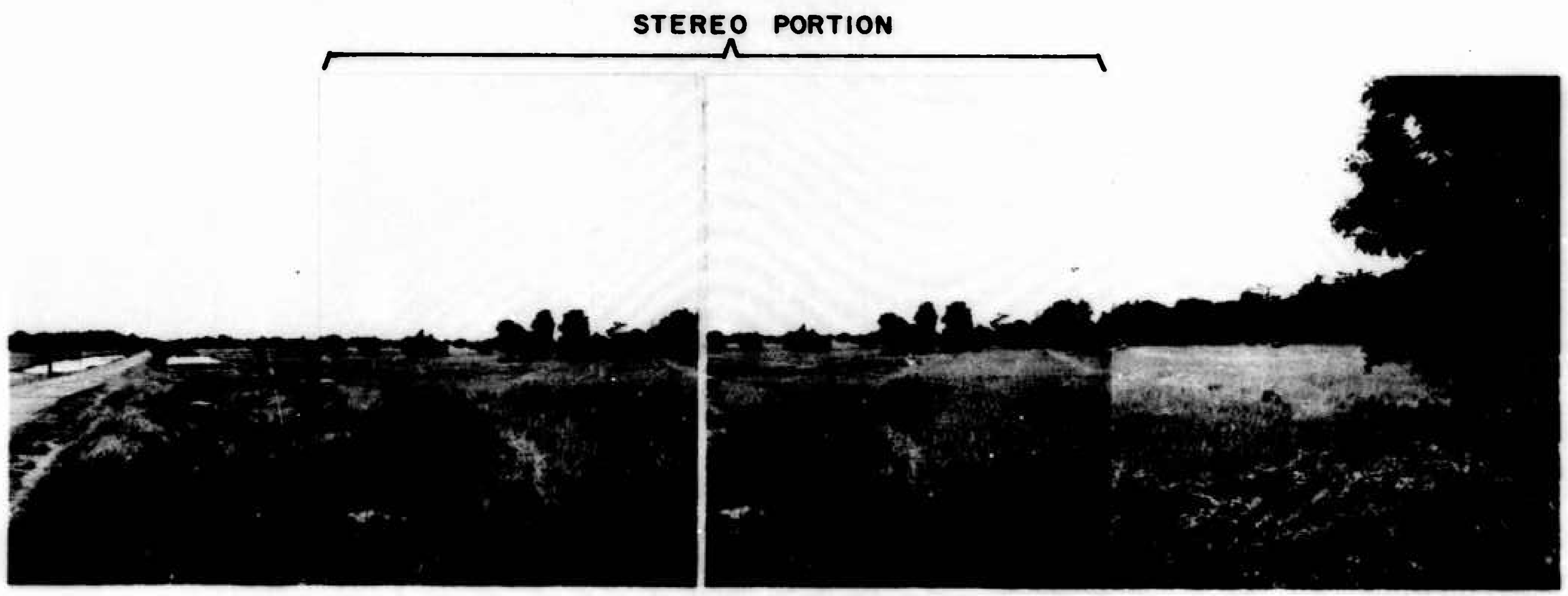



Fig. 60. Terraced paddies in midportion of transition zone, site SG-65 (17 September 1964)


Fig. 61. Terraced paddies on broad regional slope, aerial mosaic, site SG-81 (January 1965)

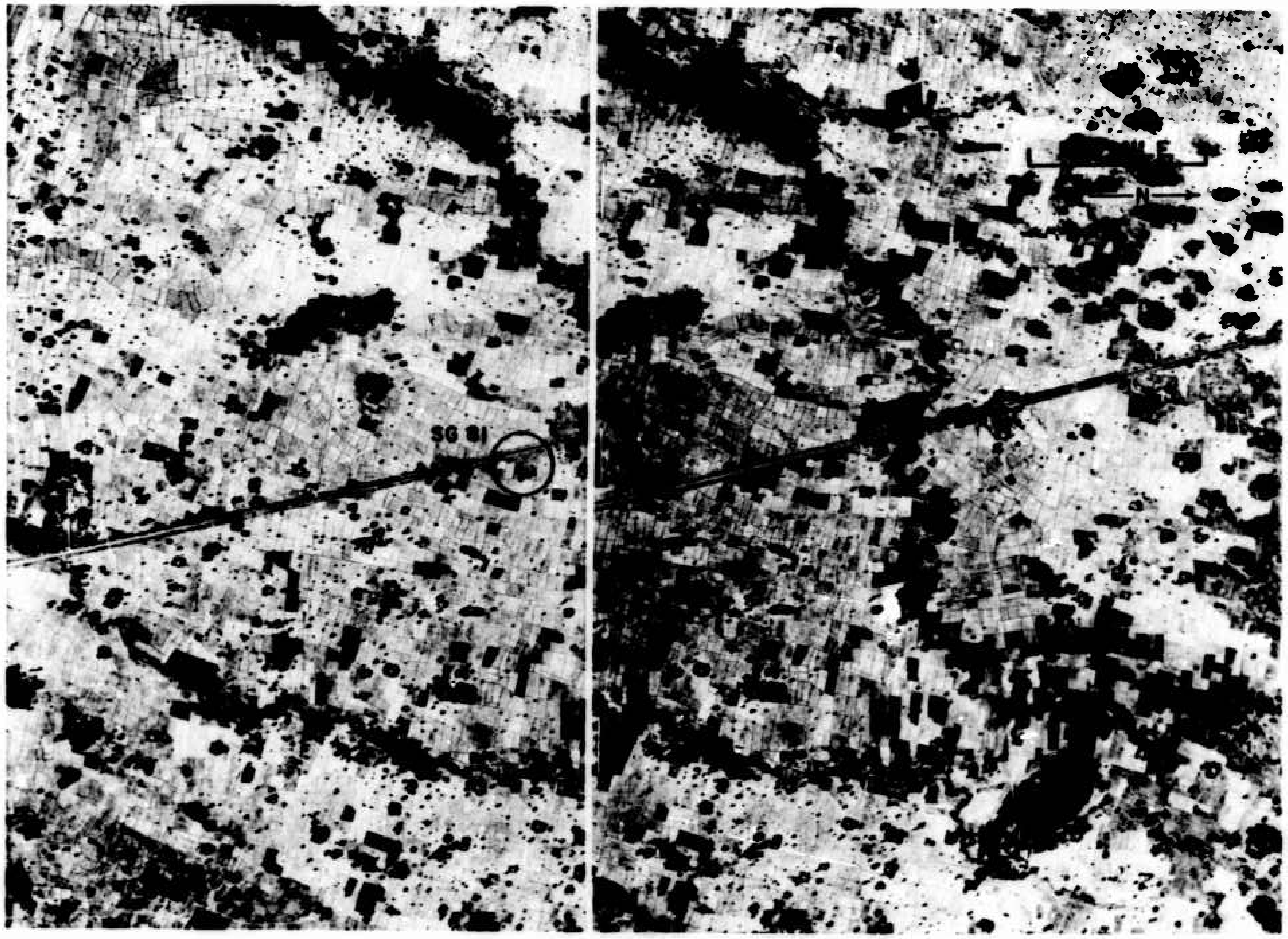



Fig. 62. Terraced paddies on broad regional slope, stereopair, site SG-81 (January 1965)

Fig. 63. Terraced paddies--view along dike B toward dike C at site SG-81 taken at photo spot 1 on dike plan in fig. 65 (September 1964)

Fig. 64. Terraced paddies--view along dike A toward dike D at site SG-81 taken at photo spot 2 on dike plan in fig. 65 (September 1964)

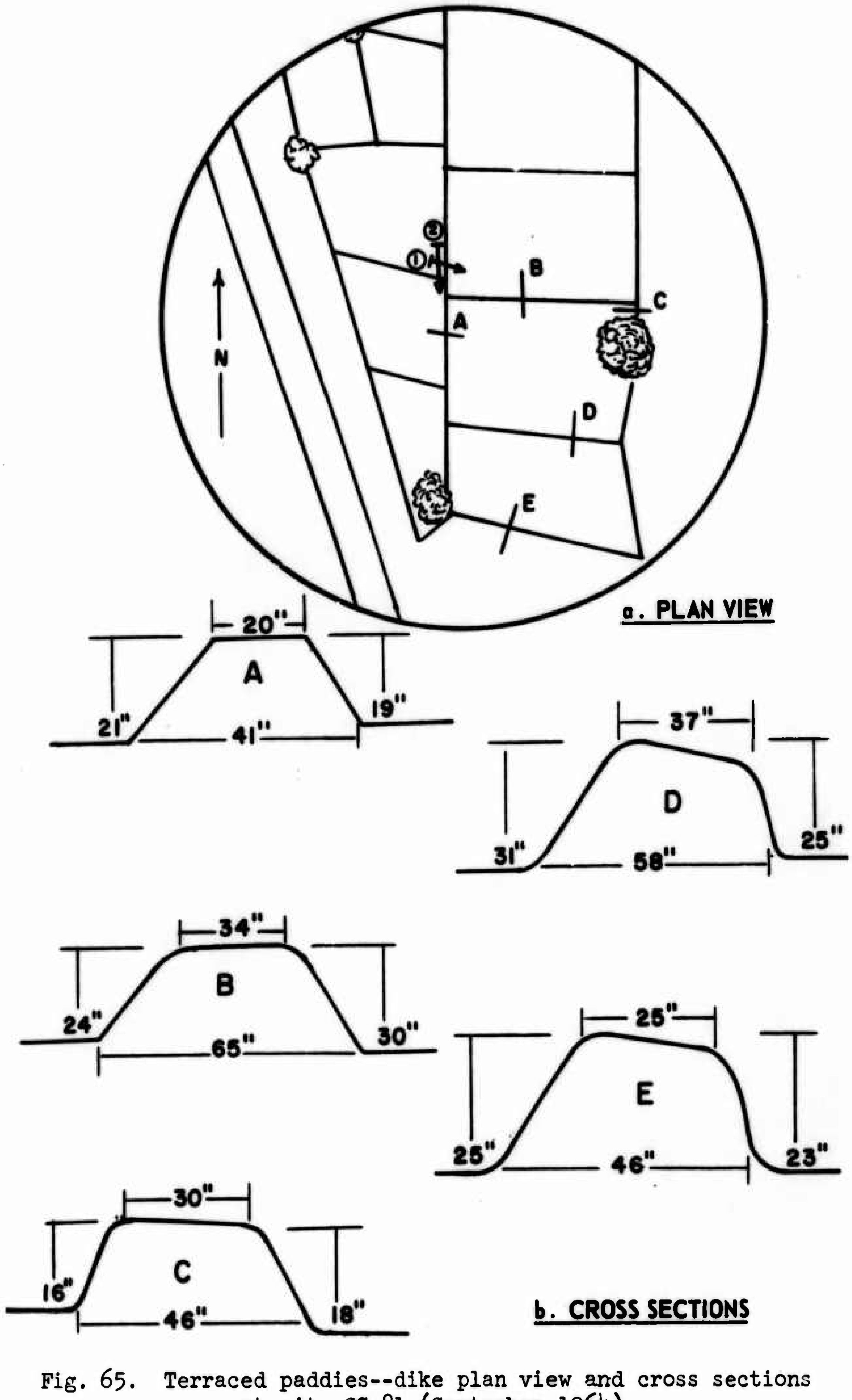



Fig. 65. Terraced paddies--dike plan view and cross sections at site SG-81 (September 1964)

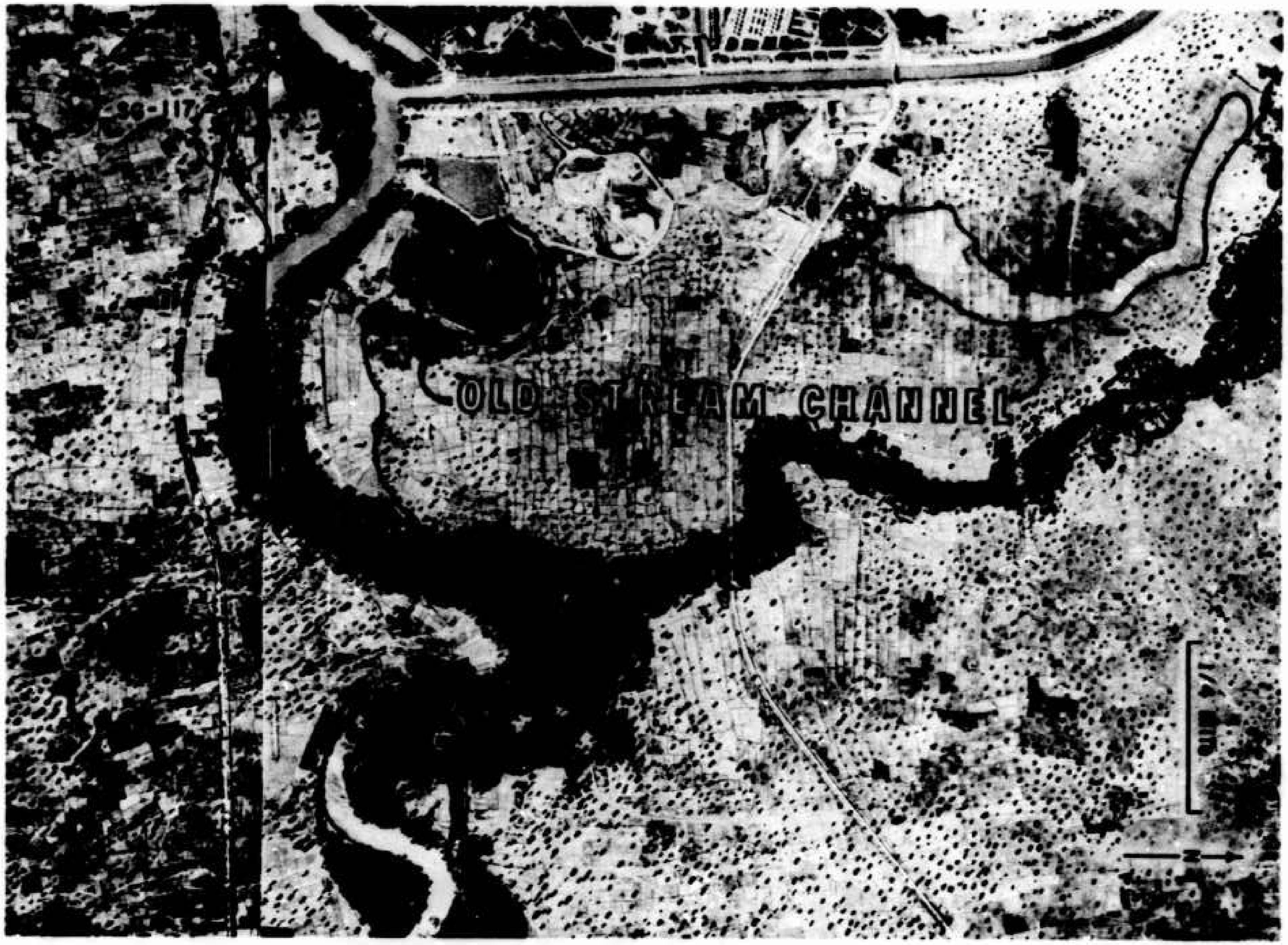



Fig. 66. Terraced paddies on side slopes of abandoned stream channel near site SG-117 (January 1965)


Fig. 67. Terraced paddies on side slopes of abandoned stream channel near site SG-117, large-scale air photo (February 1965)

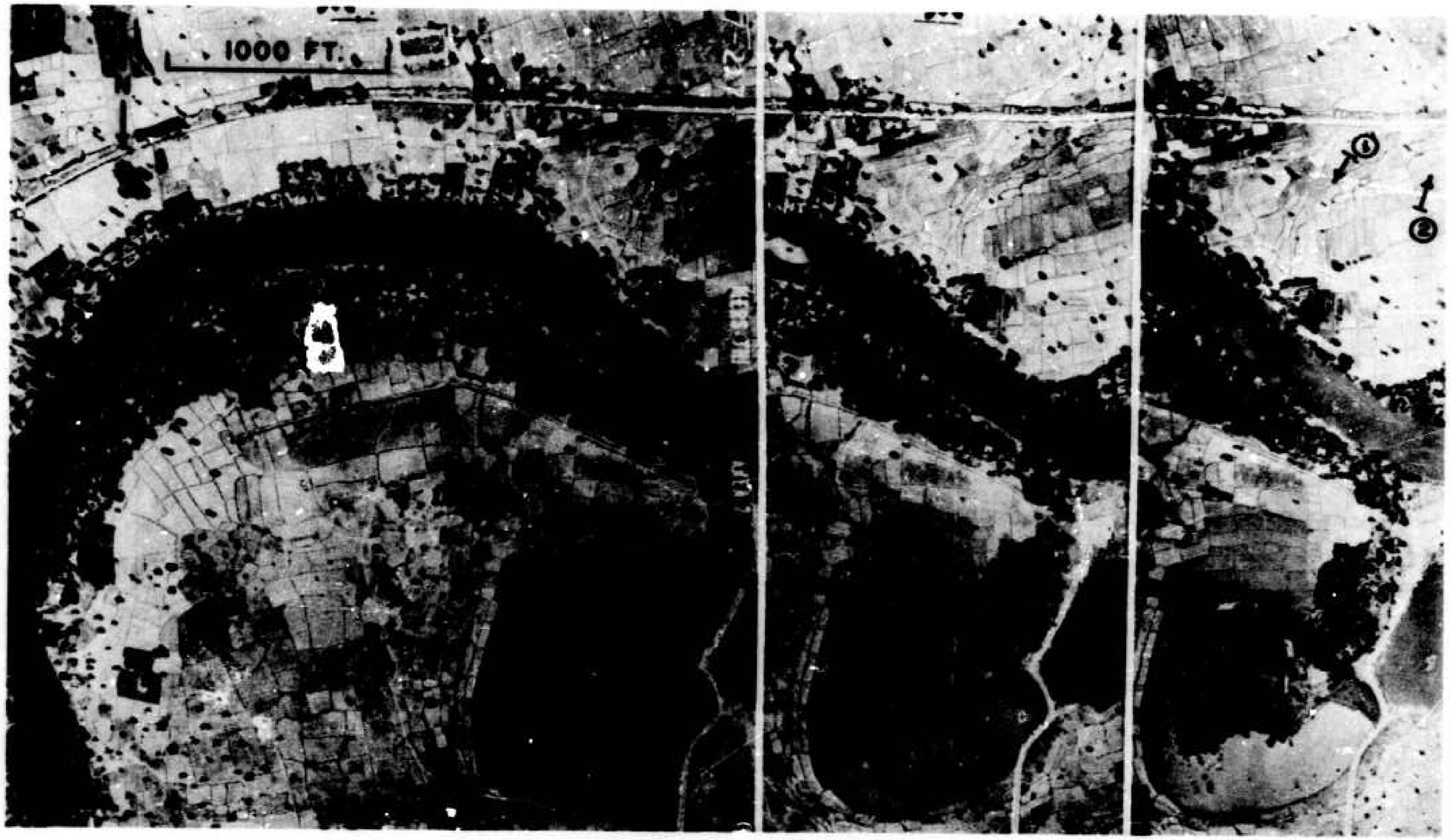



Fig. 68. Terraced paddies--abandoned stream channel near site SG-117, large-scale stereotriplet (February 1965)

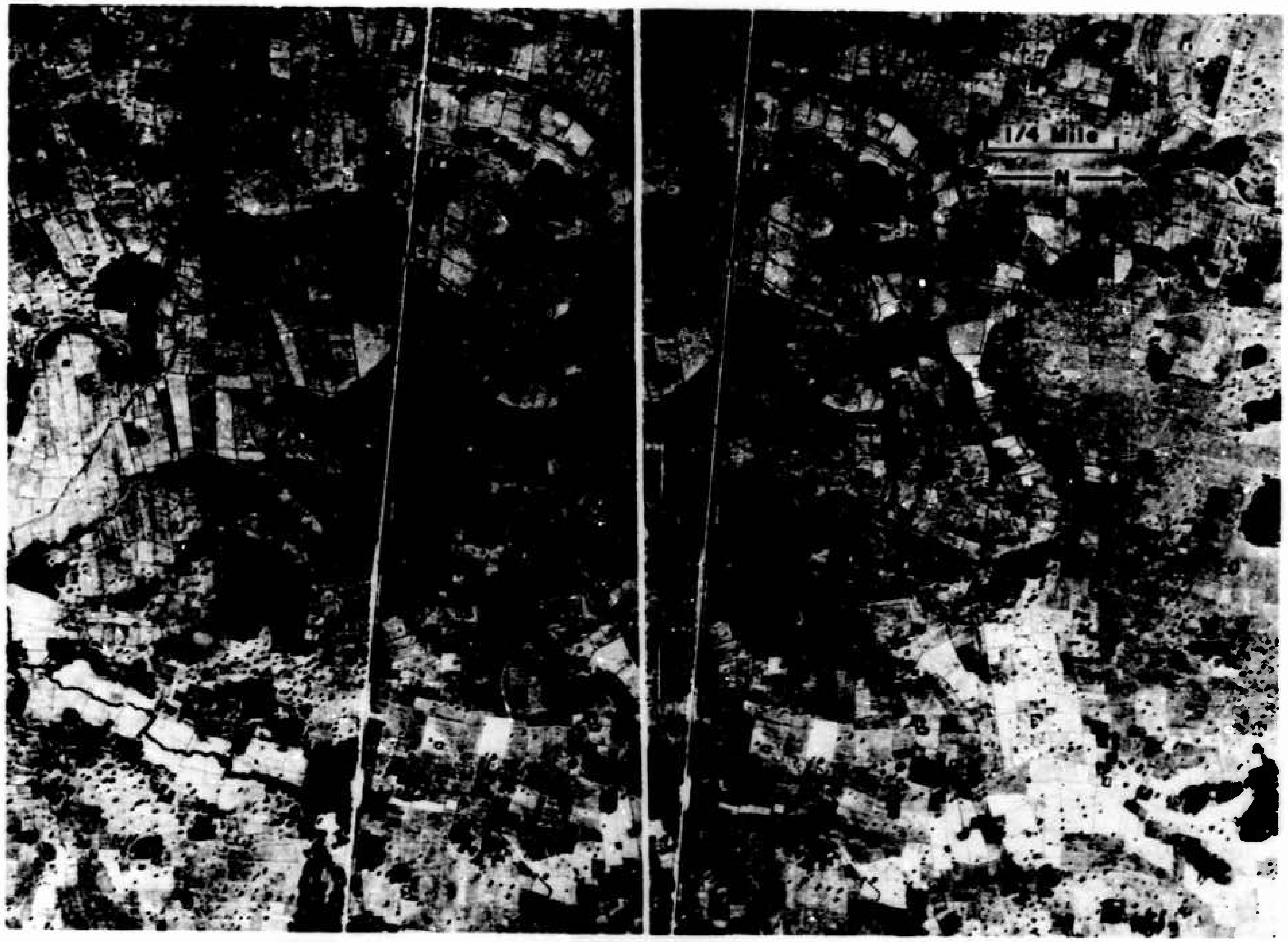



Fig. 69. Terraced paddies along sides of abandoned stream channel in flat area (January 1965)

1

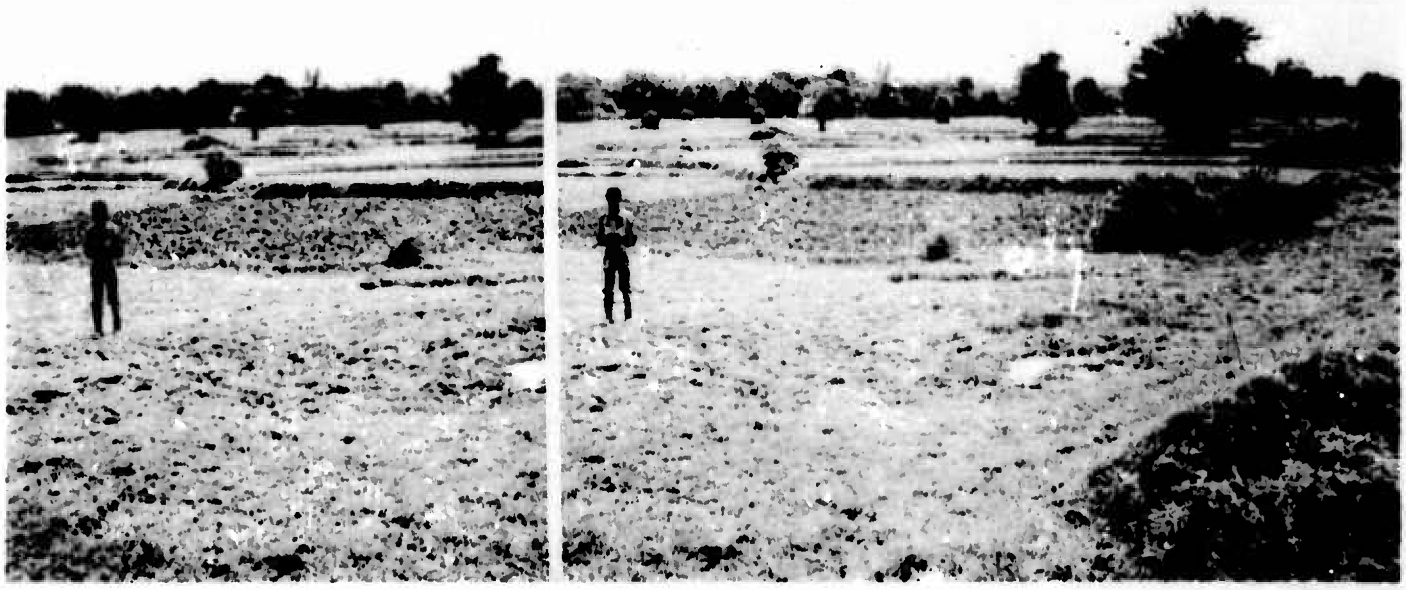


Fig. 70. Terraced paddies--view north from road toward terraces on side slopes of abandoned channel, site SG-117 (September 1964)

2

Fig. 71. Terraced paddies--view south toward road showing terraces on side slope of abandoned channel, site SG-117 (September 1964)


Fig. 72. Terraced paddies along sides of valley bounding active stream in flat area near site SG-105 (January 1965)

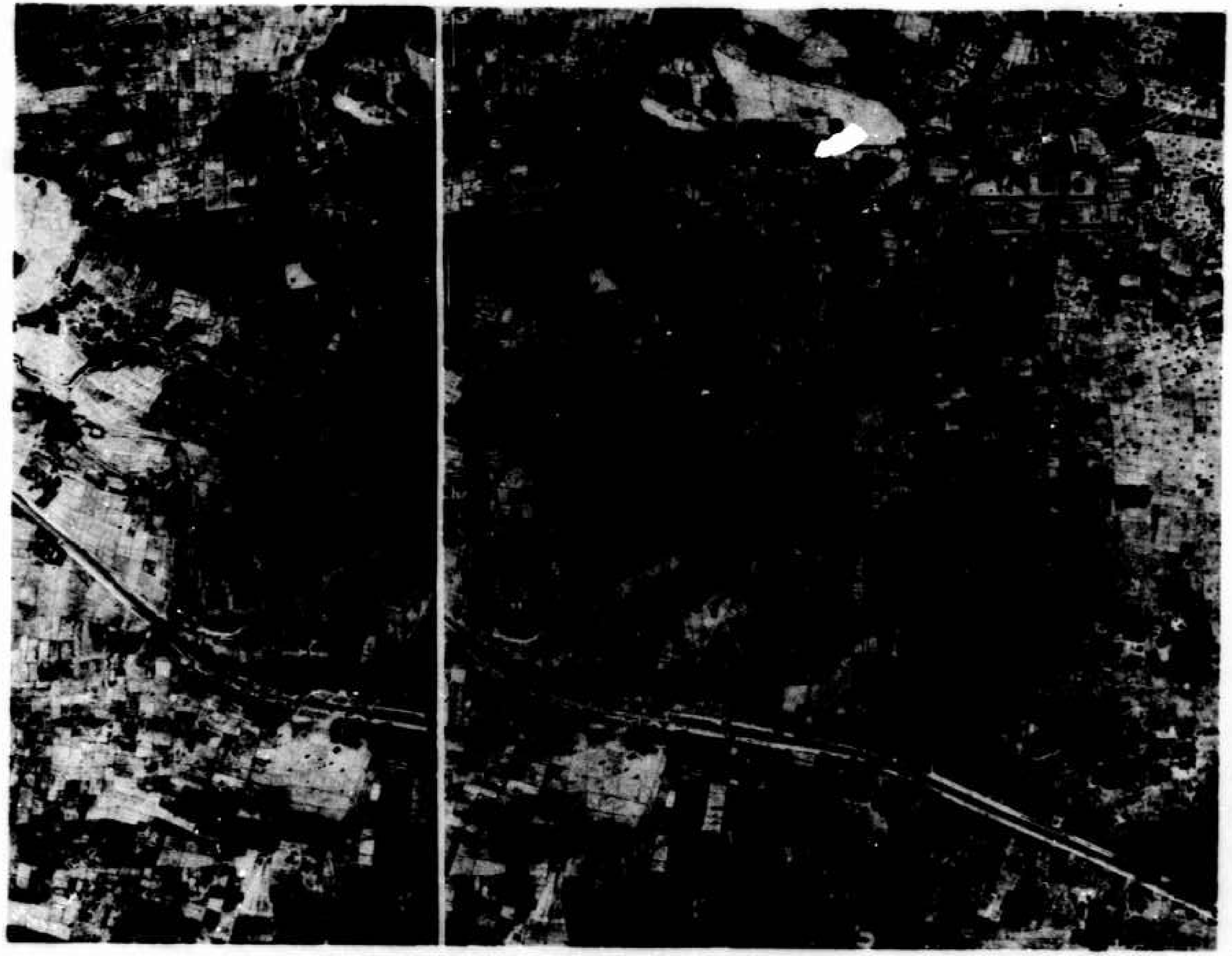


Fig. 73. Terraced paddies lining stream valley near site SG-105, stereopair (January 1965)

Fig. 74. Terraced paddies--view west-southwest over site SG-105 (September 1964)

Fig. 75. Terraced paddies--view east over site SG-105 (September 1964)

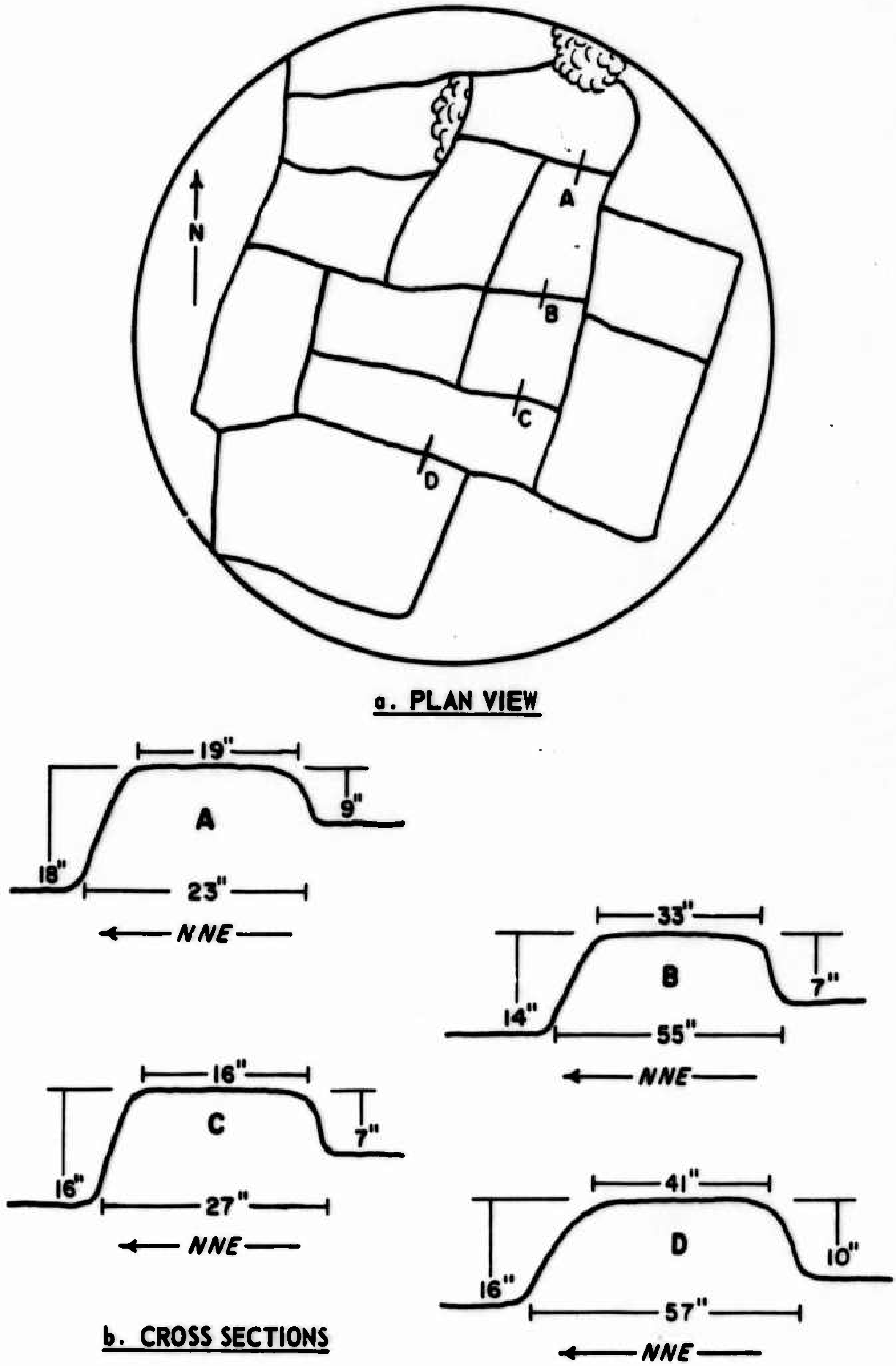



Fig. 76. Terraced paddies--dike plan view and cross sections at site SG-105 (September 1964)


Fig. 77. Terraced paddies on natural levee sites SG-115 and SG-116 (January 1965)

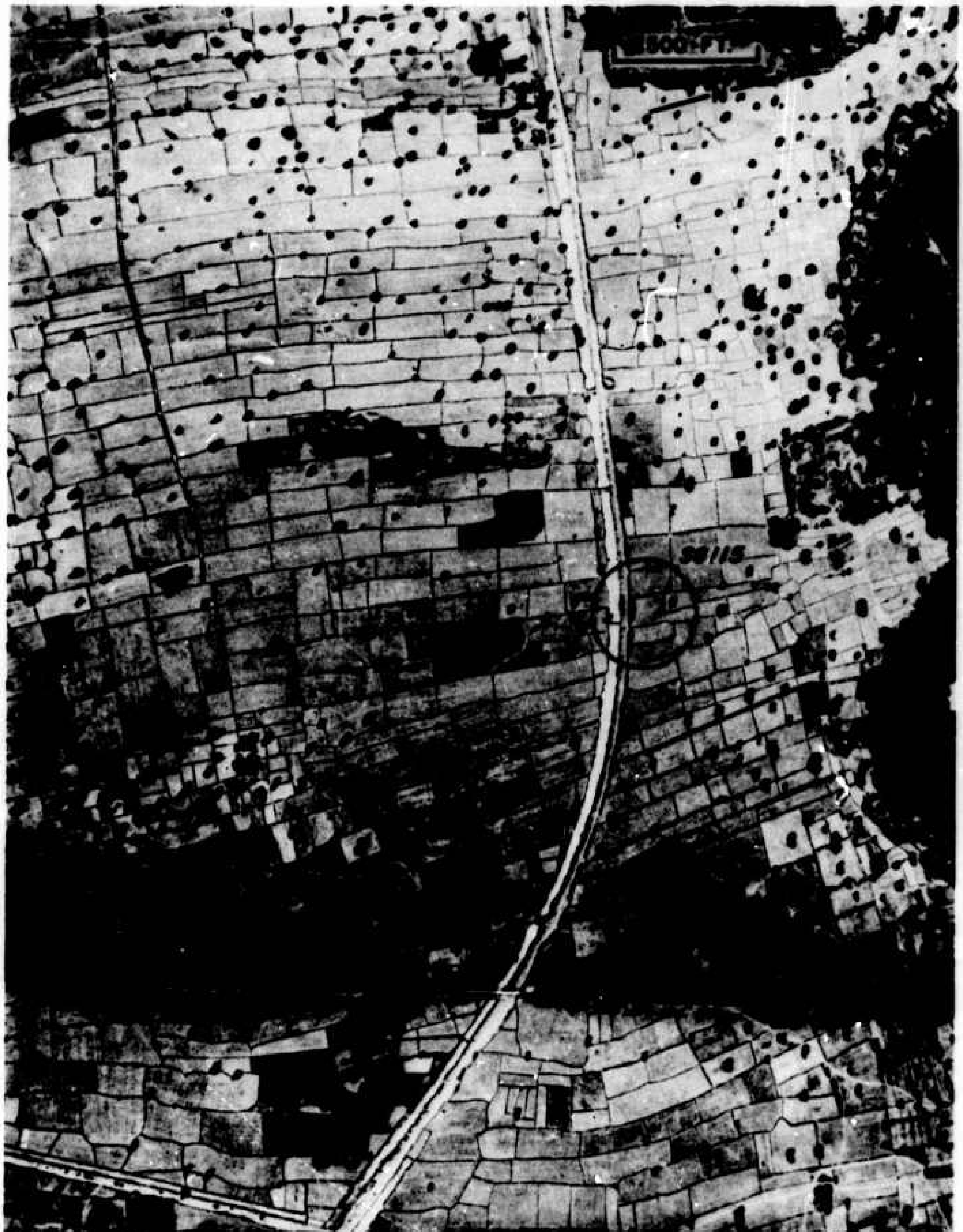



Fig. 78. Terraced paddies on natural levee, large-scale air photo, site SG-115 (February 1965)


Fig. 79. Terraced paddies on natural levee at site SG-41 near Chiang Mai
(1953 air photo; 1964 ground photo)

Fig. 80. Terraced paddies--view north from spot 1 shown in the dike plan in fig. 82 along dike A at site SG-115 (September 1964)

Fig. 81. Terraced paddies--view north from spot 2 shown in the dike plan in fig. 83 at site SG-116 (September 1964)

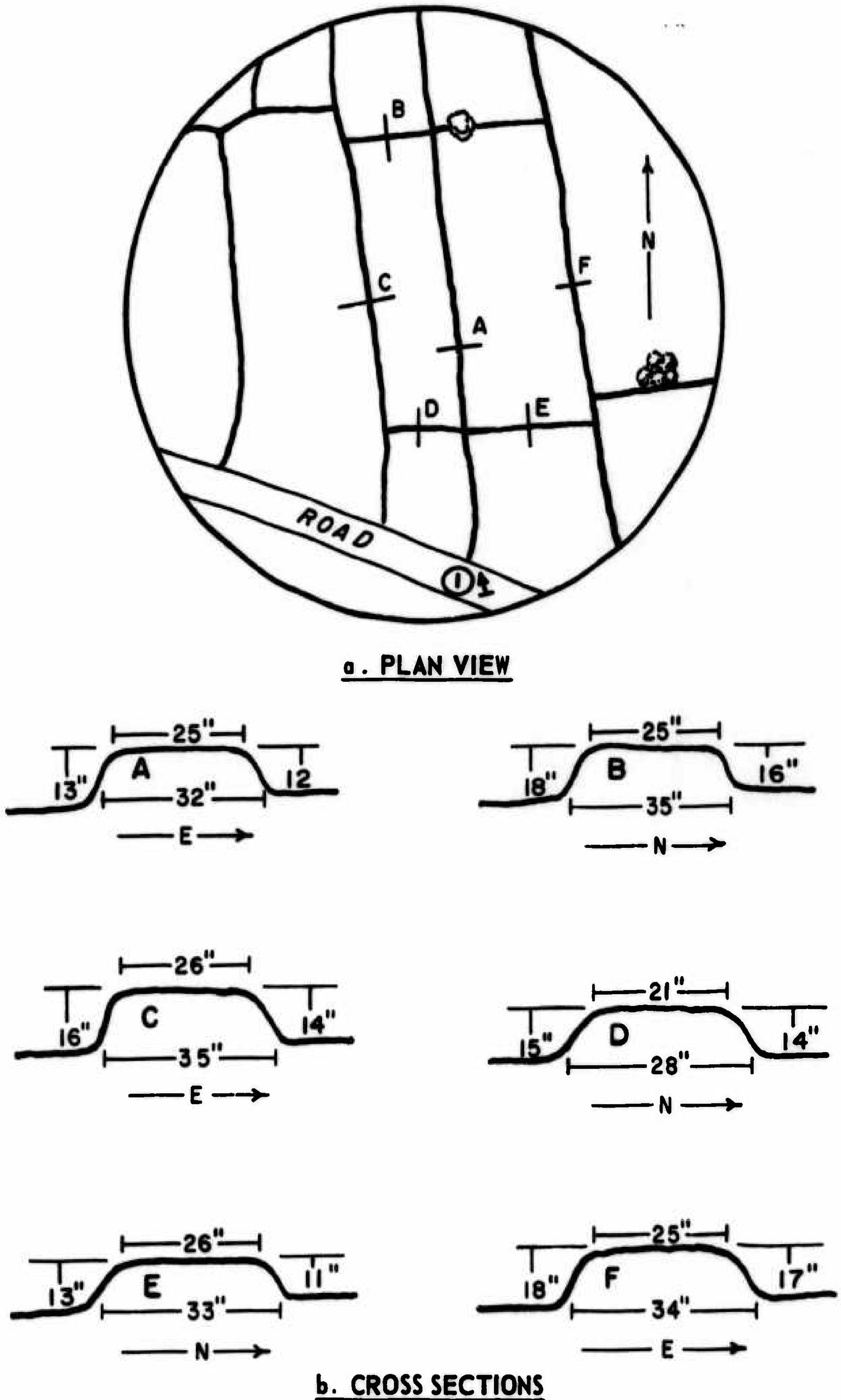



Fig. 82. Terraced paddies--dike plan view and cross sections at site SG-115 (September 1964)

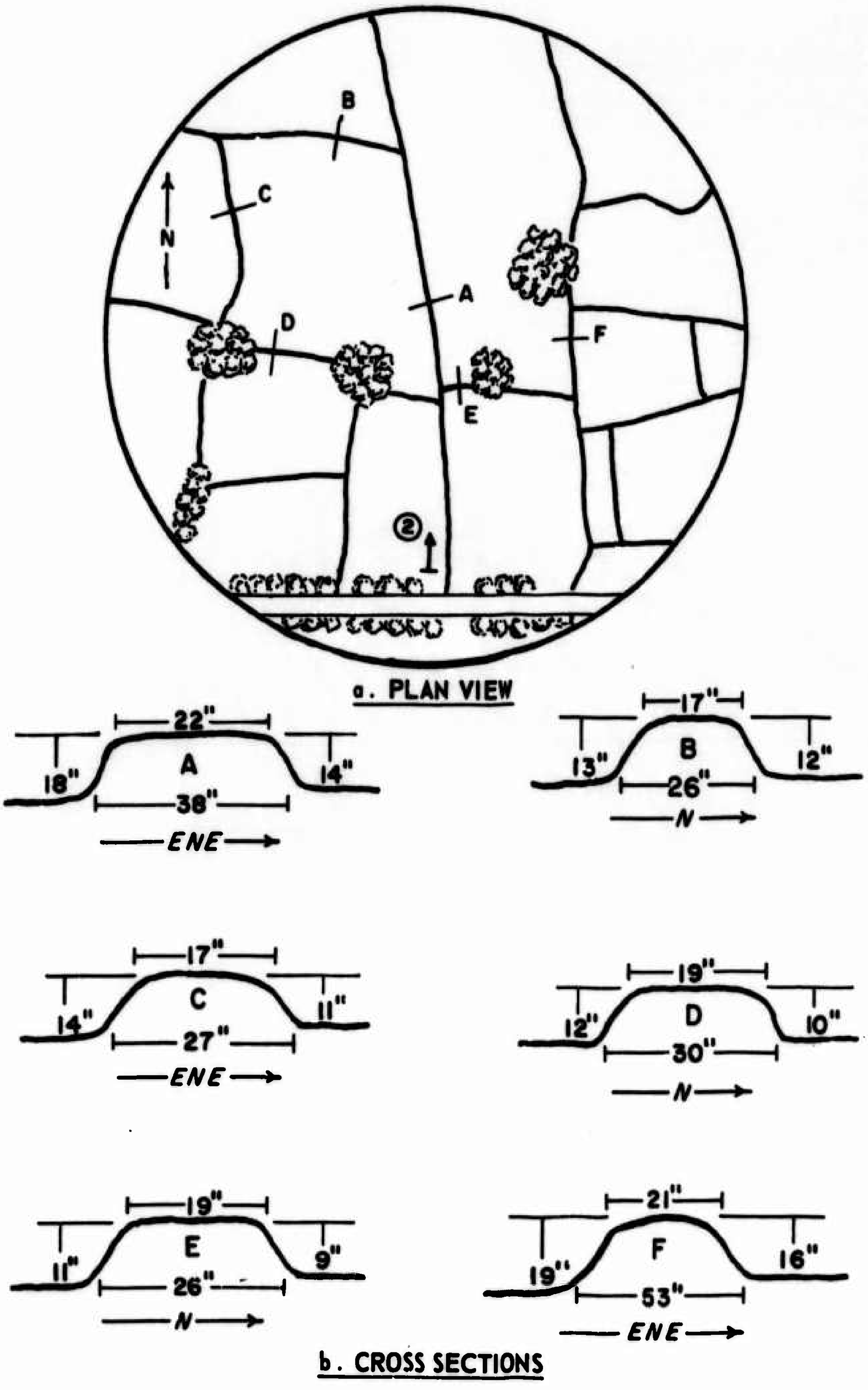



Fig. 83. Terraced paddies--dike plan view and cross sections at site SG-116 (September 1964)


Fig. 84. Paddies with random arrangement adjusted to undulating terrain of a natural levee, site SG-114 (February 1965)

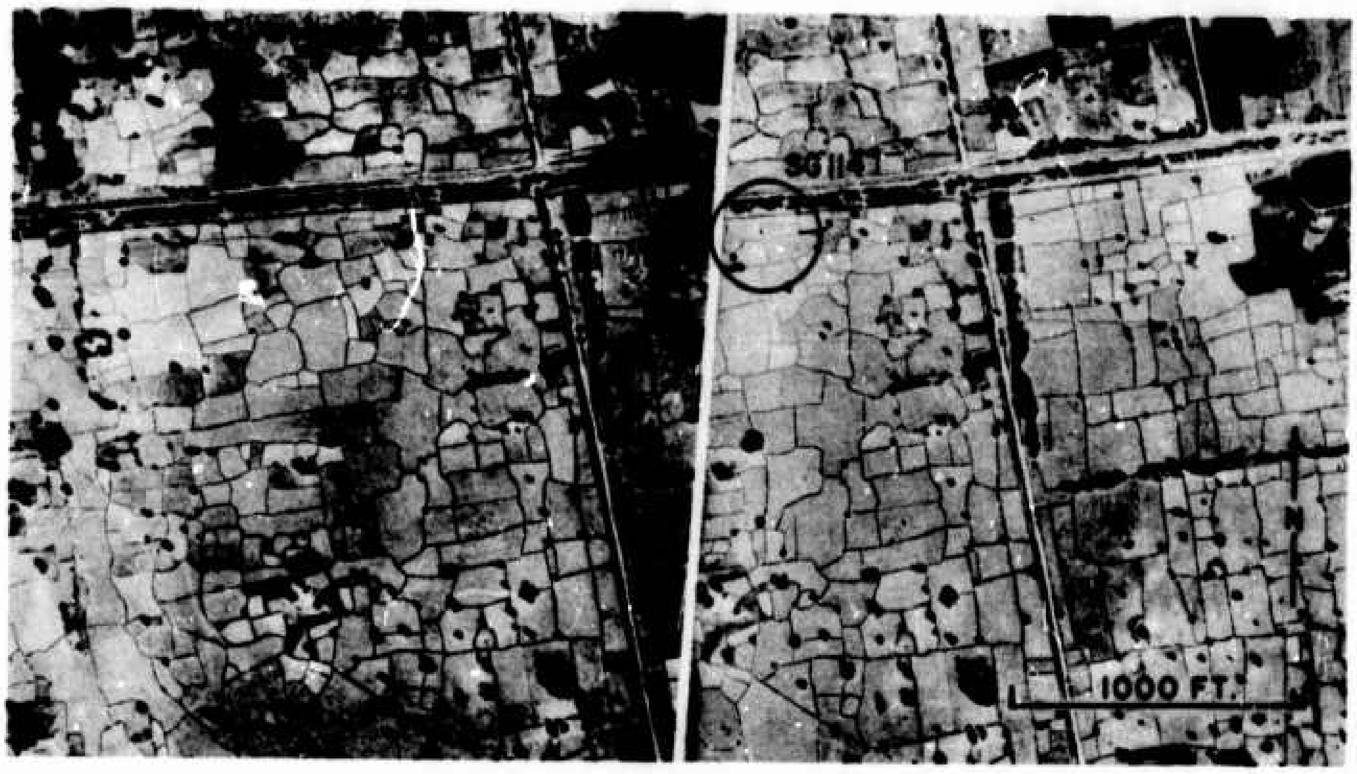



Fig. 85. Paddies with random arrangement on undulating terrain of a natural levee, stereopair, site SG-114 (February 1965)

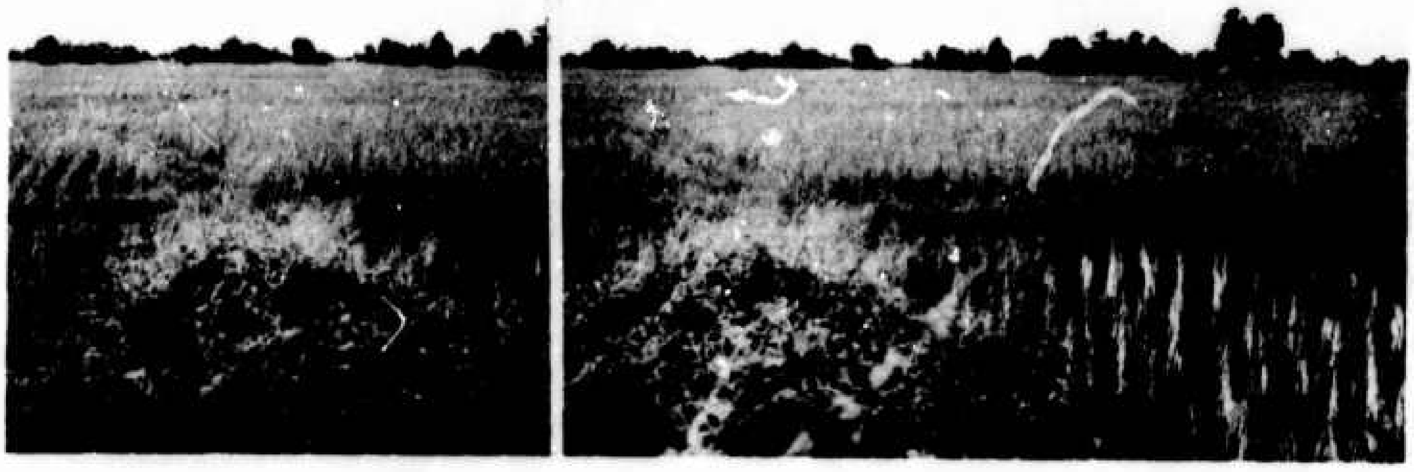


Fig. 86. Paddies with random arrangement--view to south along dike G (see fig. 87) at site SG-114 (September 1964)

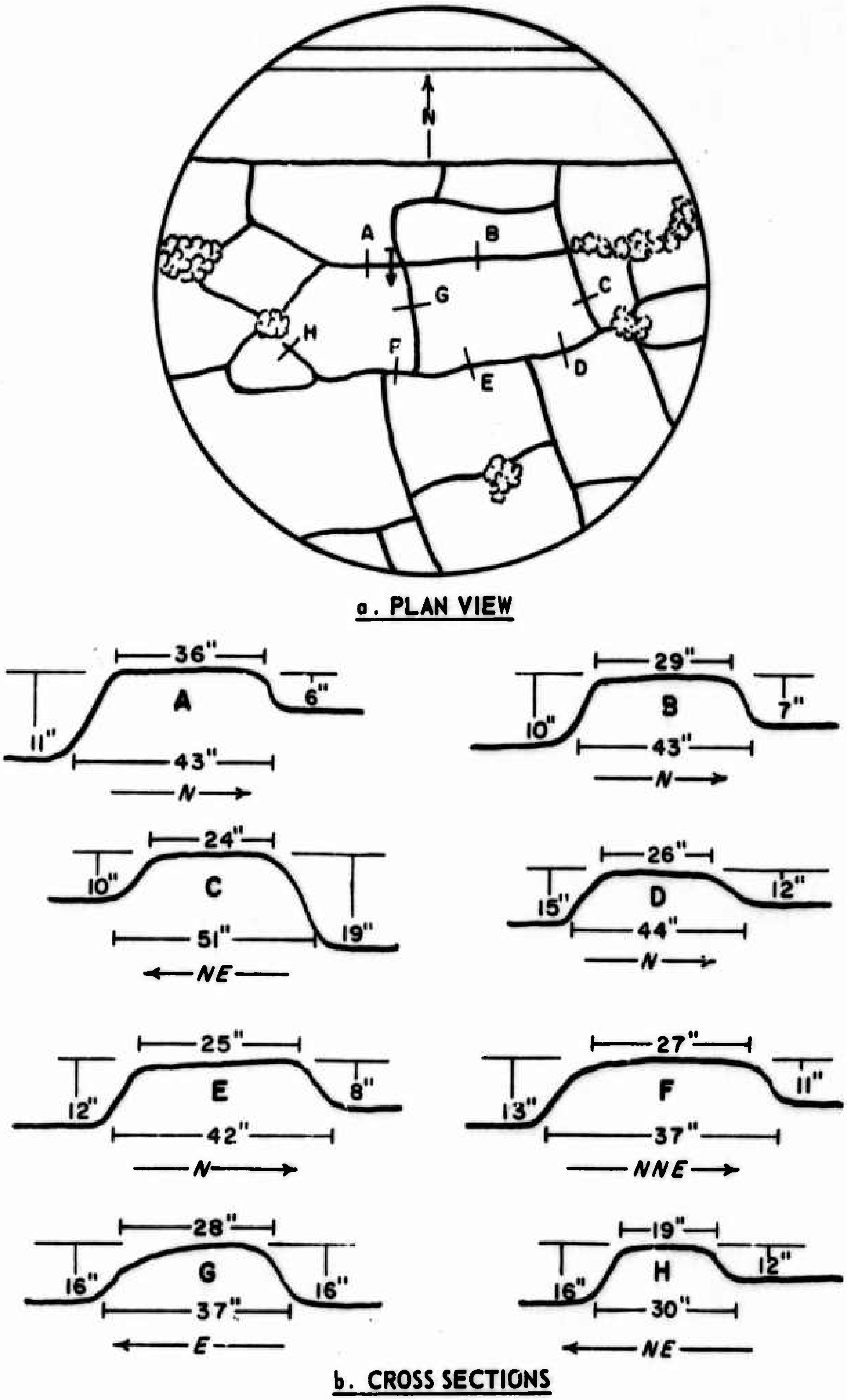



Fig. 87. Paddies with random arrangement--dike plan view and cross sections at site SG-114 (September 1964)


Fig. 88. Paddies with random arrangement on flat terrain, site SG-60 (January 1965 air photo; September 1964 ground photo)

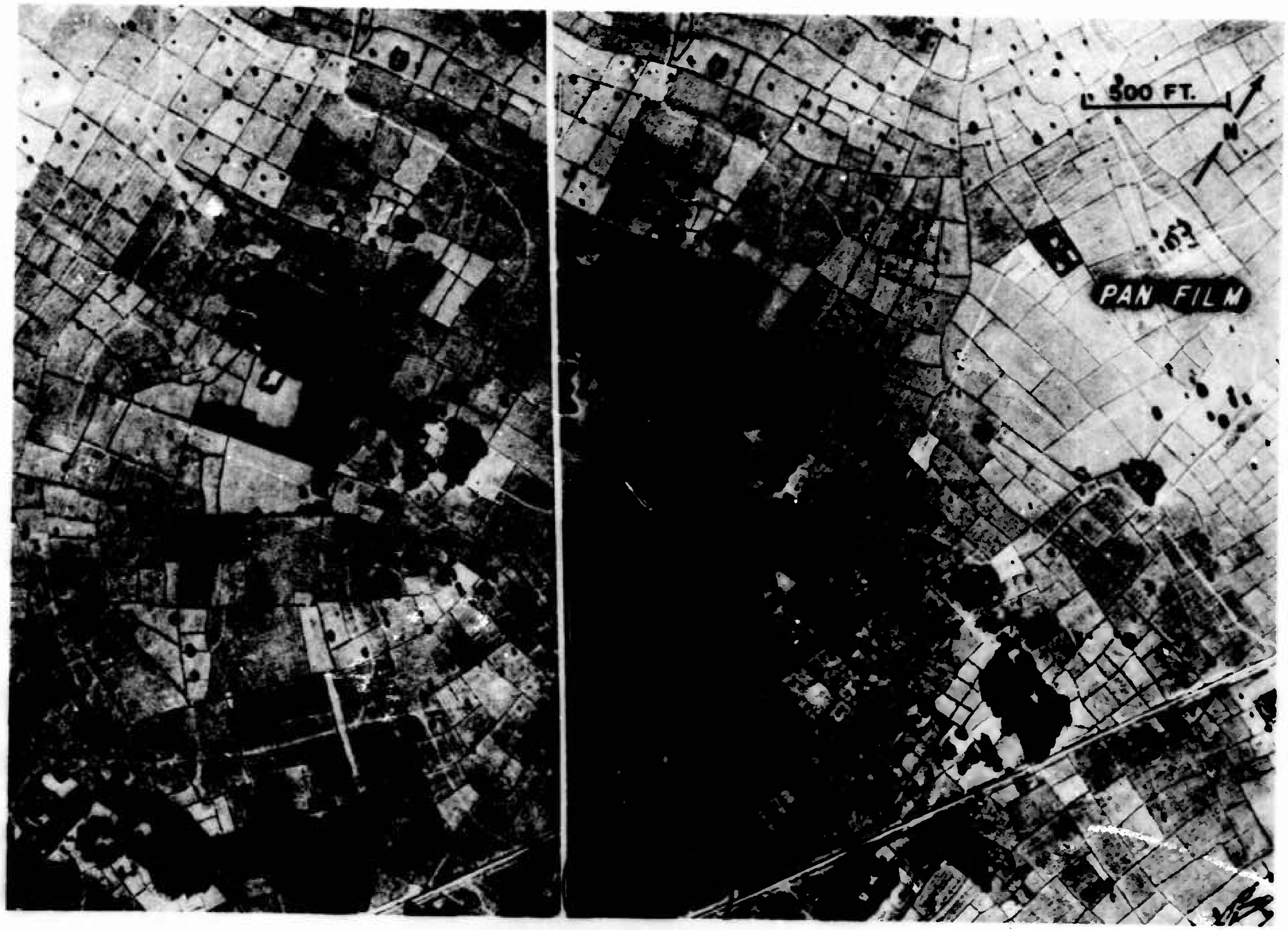



Fig. 89. Paddies with random arrangement on flat terrain, panchromatic stereopair, site SG-60 (February 1965)

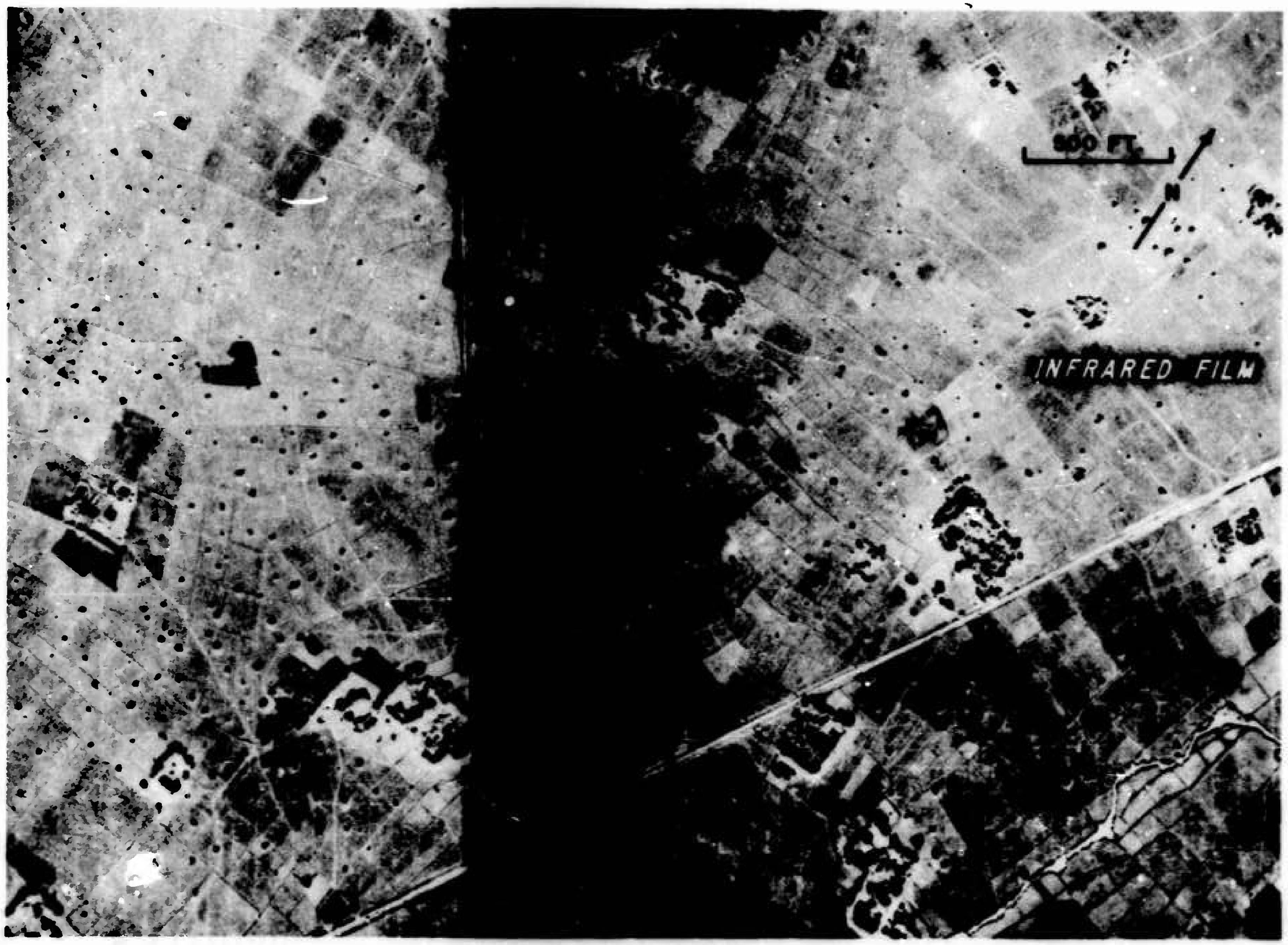



Fig. 90. Paddies with random arrangement on flat terrain, infrared stereopair, site SG-60
(February 1965)

1

2

3

Fig. 91. Paddies with random arrangement--dikes on flat terrain at site SG-60 (numbers refer to photo spot locations on dike plan in fig. 92) (September 1964)

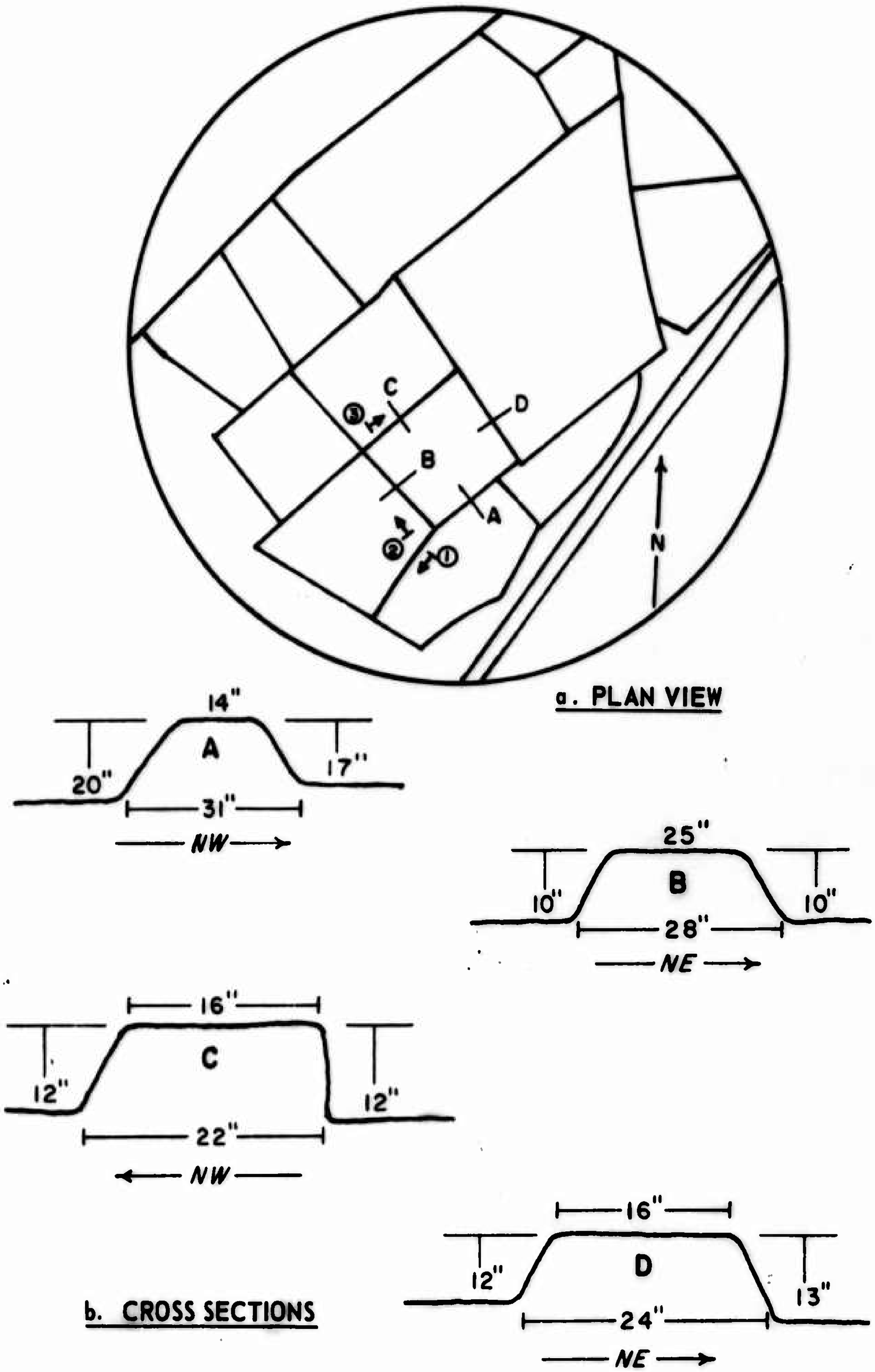



Fig. 92. Paddies with random arrangement--dike plan view and cross sections at site SG-60 (September 1964)

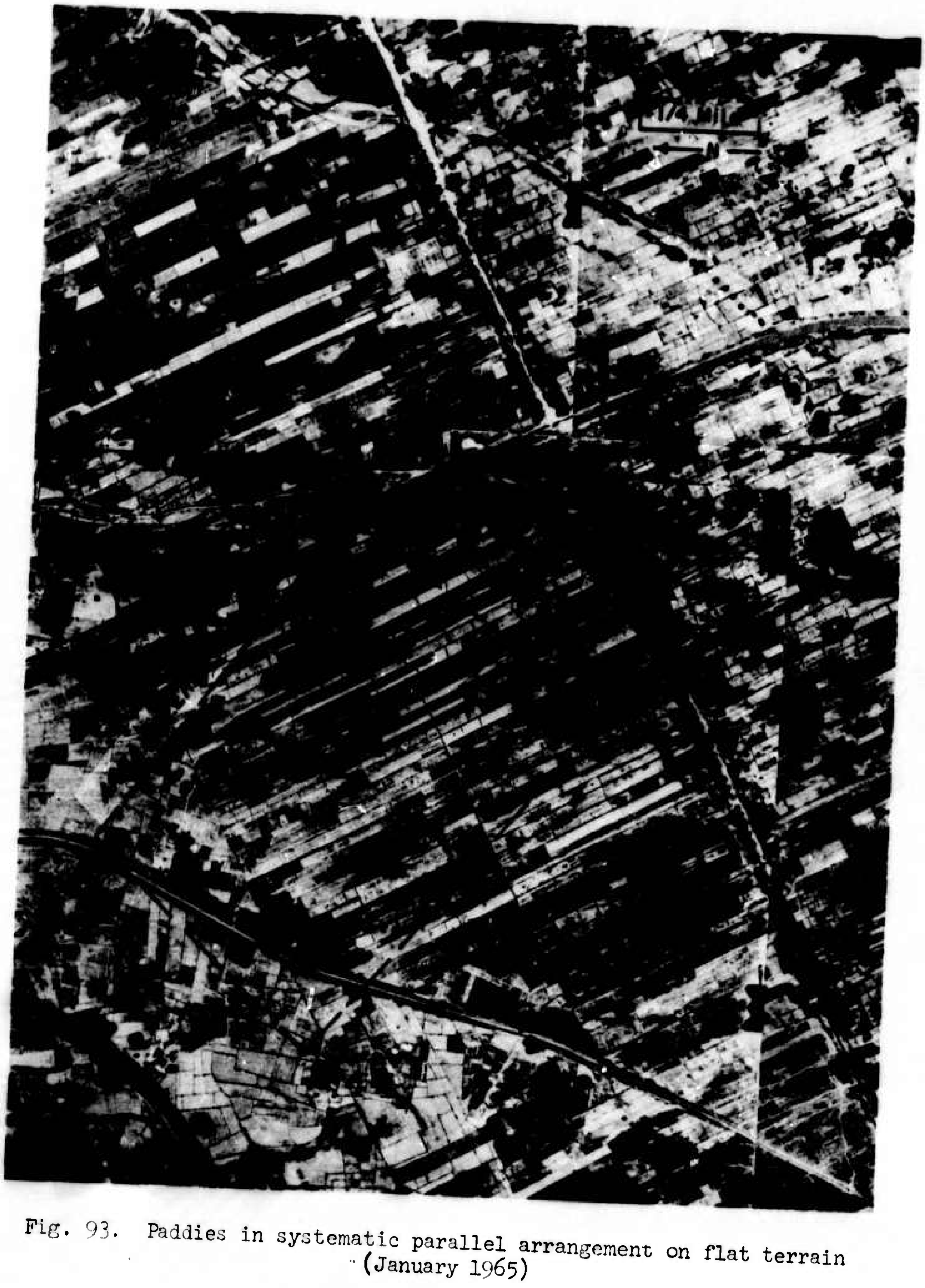


Fig. 93. Paddies in systematic parallel arrangement on flat terrain (January 1965)

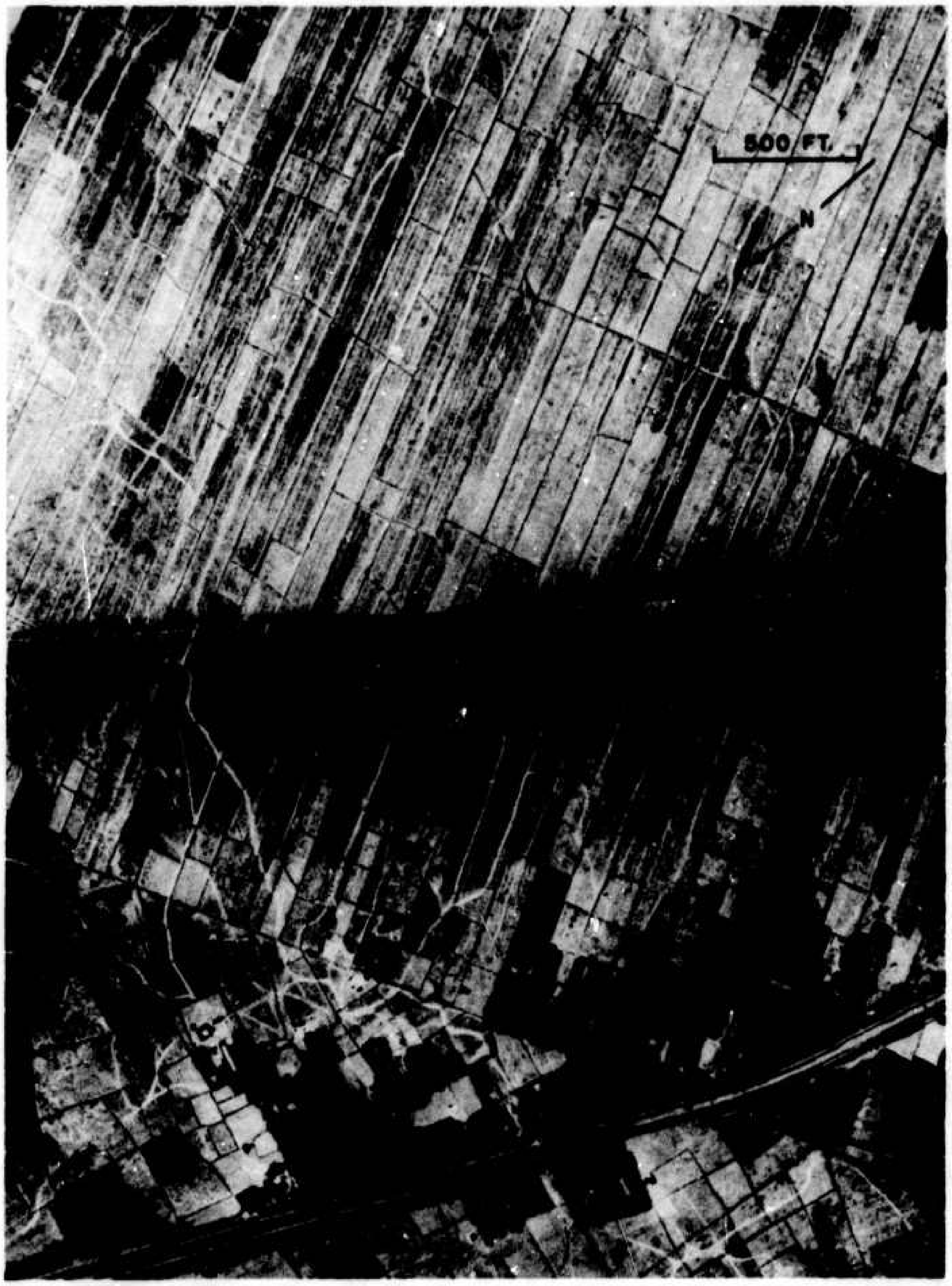



Fig. 94. Paddies in systematic parallel arrangement on flat terrain--part of fig. 93 at larger scale (February 1965)

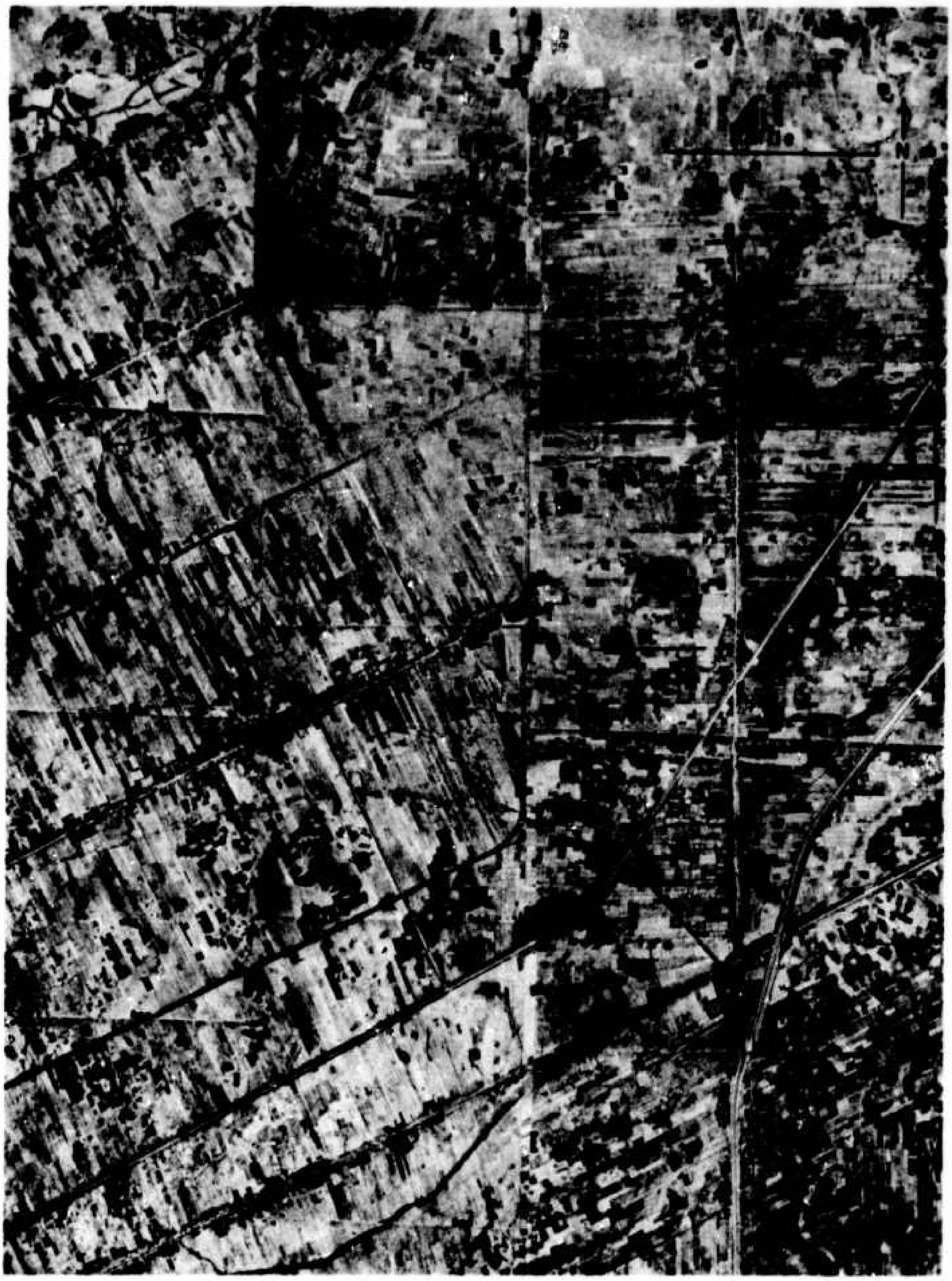


Fig. 95. Paddies in systematic parallel arrangement on flat terrain--small-scale aerial mosaic (January 1965)

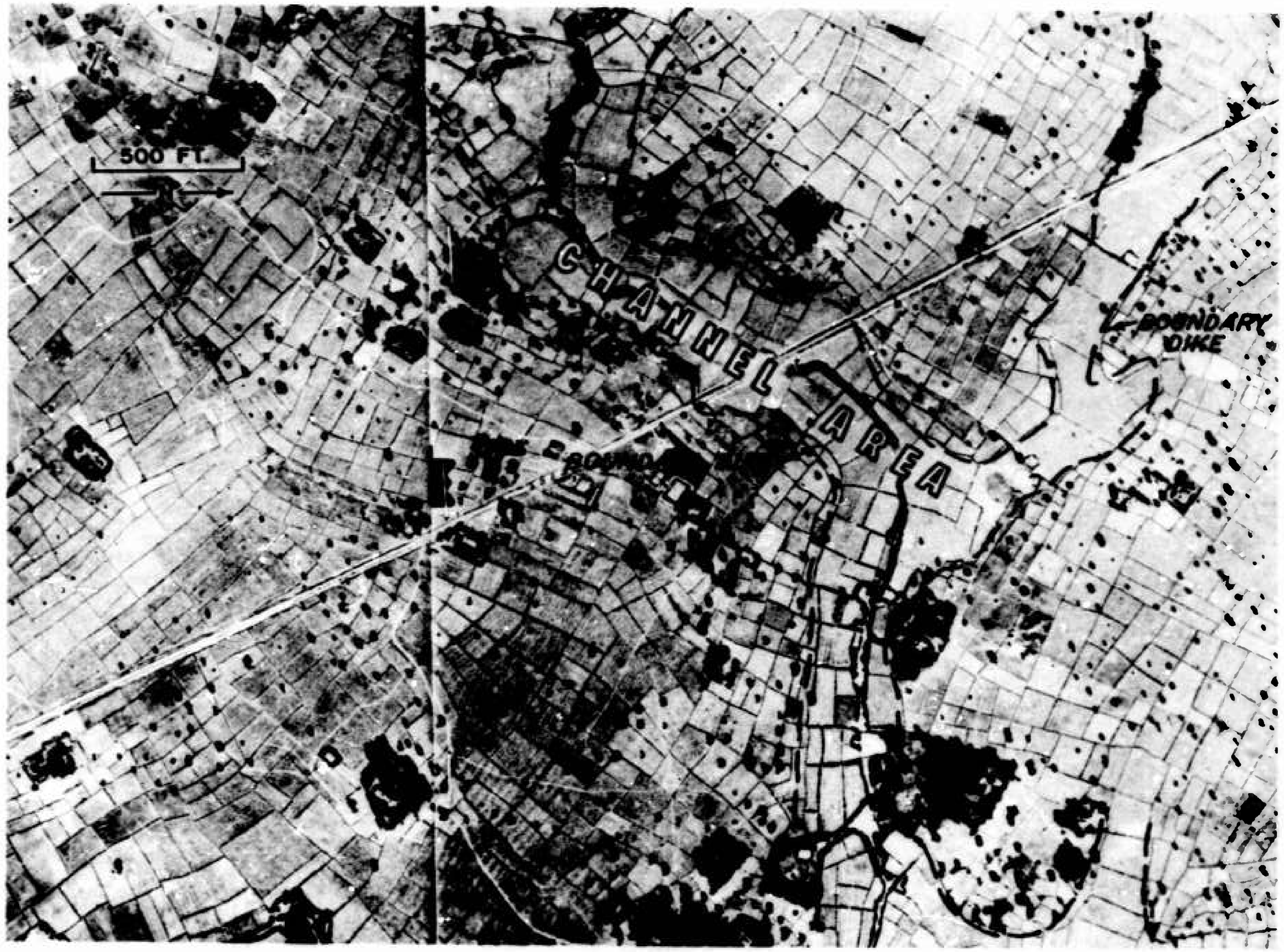



Fig. 96. Boundary dikes associated with abandoned channel and stream channel (February 1965)

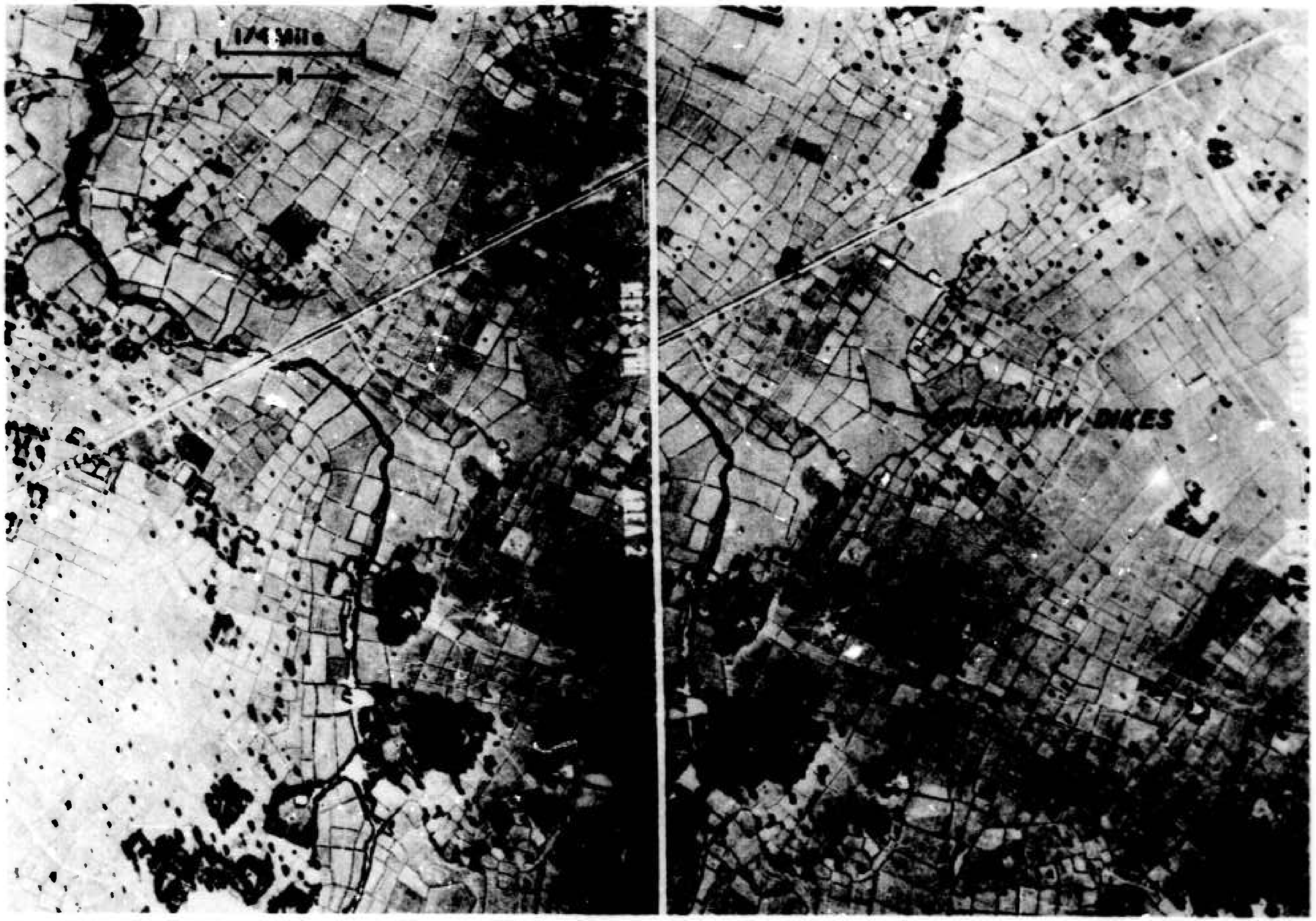



Fig. 97. Boundary dikes associated with abandoned channel and stream channel, stereopair (February 1965)


Fig. 98. Boundary dikes associated with reclaimed land in a tidal flat, site SG-163 (1953)

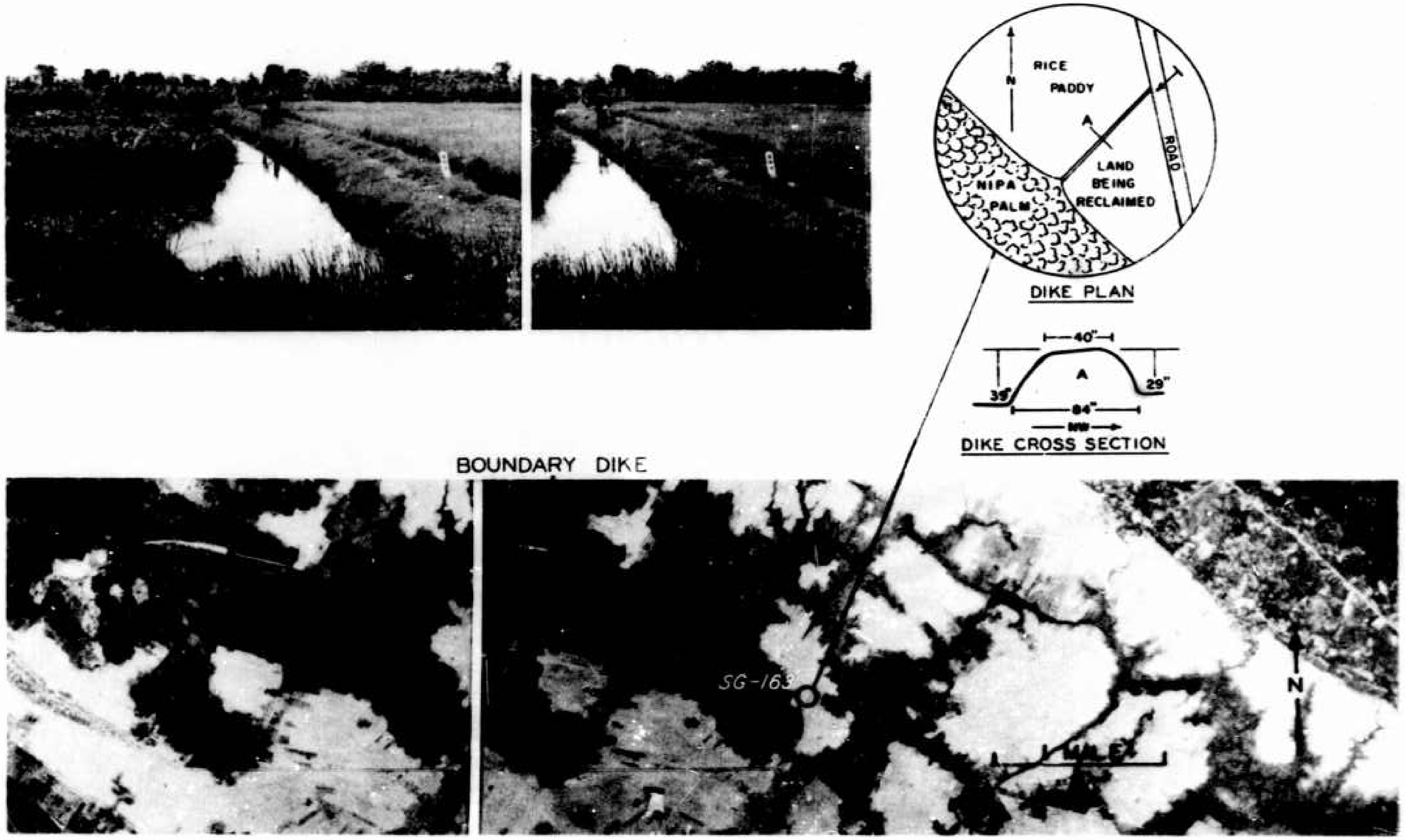



Fig. 99. Boundary dikes associated with reclaimed land in a tidal flat, site SG-163 (October 1964; ground photo taken from location indicated on dike plan)

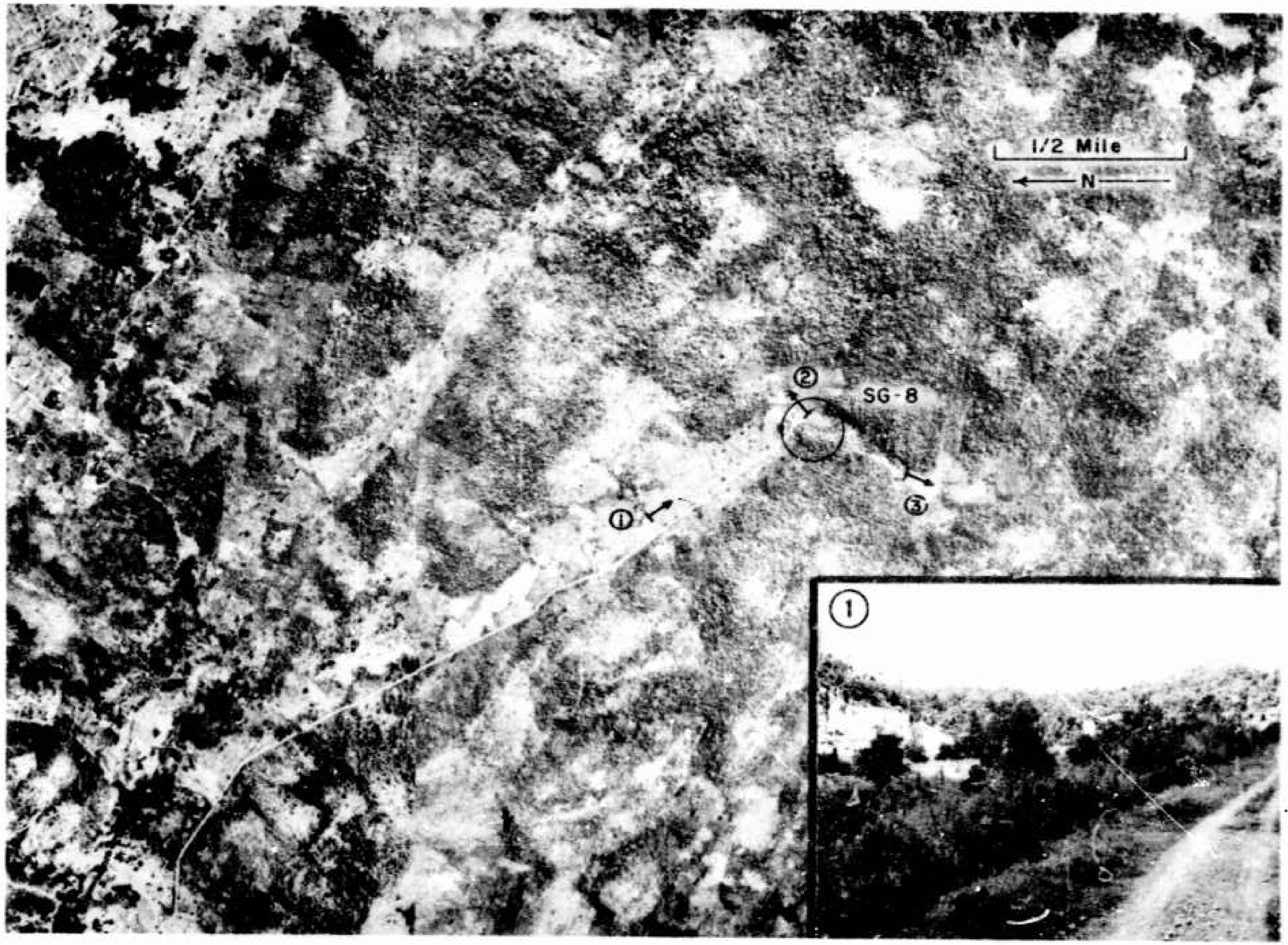



Fig. 100. Mountain valley terrain, site SG-8 (January 1965 air photo; September 1964 ground photo)

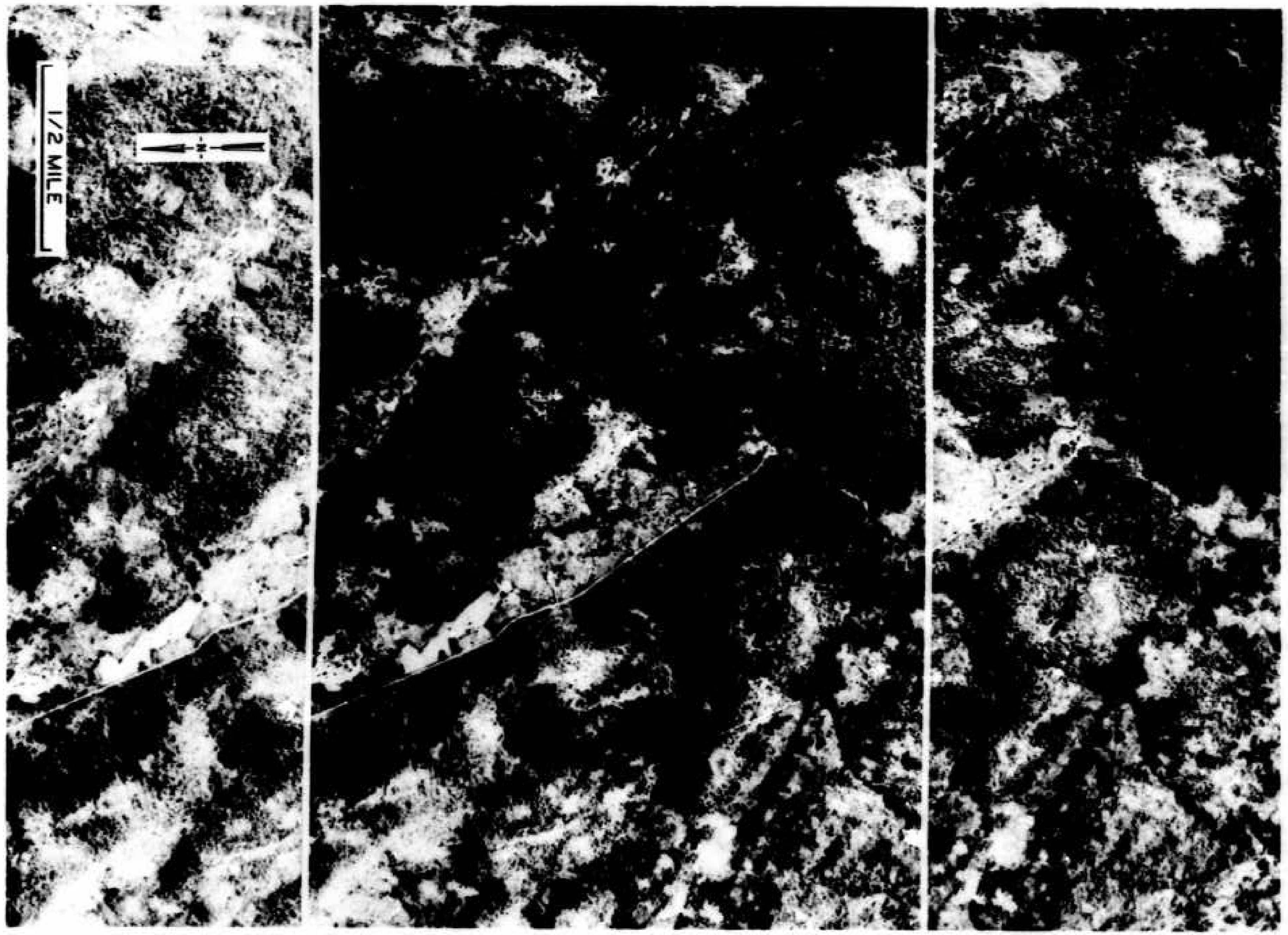



Fig. 101. Mountain valley terrain, stereotriplet, site SG-8 (January 1965)

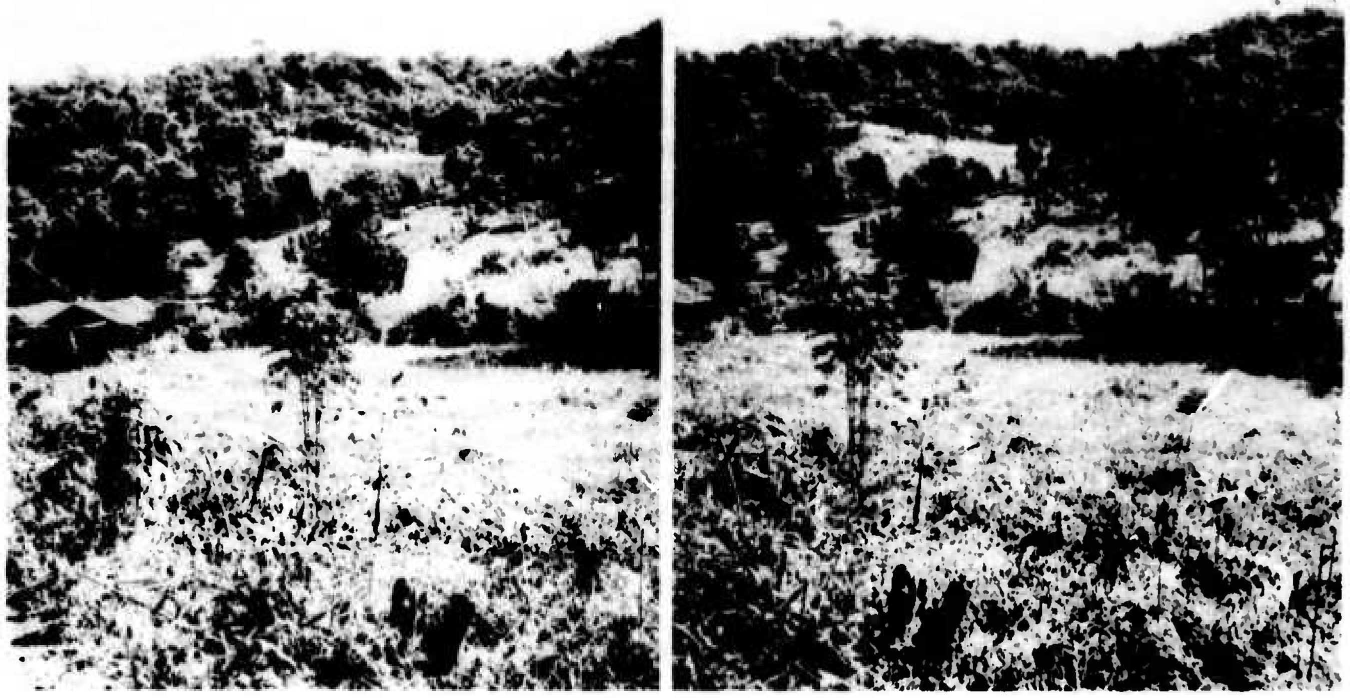


Fig. 102. Mountain valley--view northeast toward valley wall at location 2 in fig. 100, site SG-8 (September 1964)

Fig. 103. Mountain valley--waterfall at head of valley at location 3 in fig. 100, site SG-8 (September 1964)

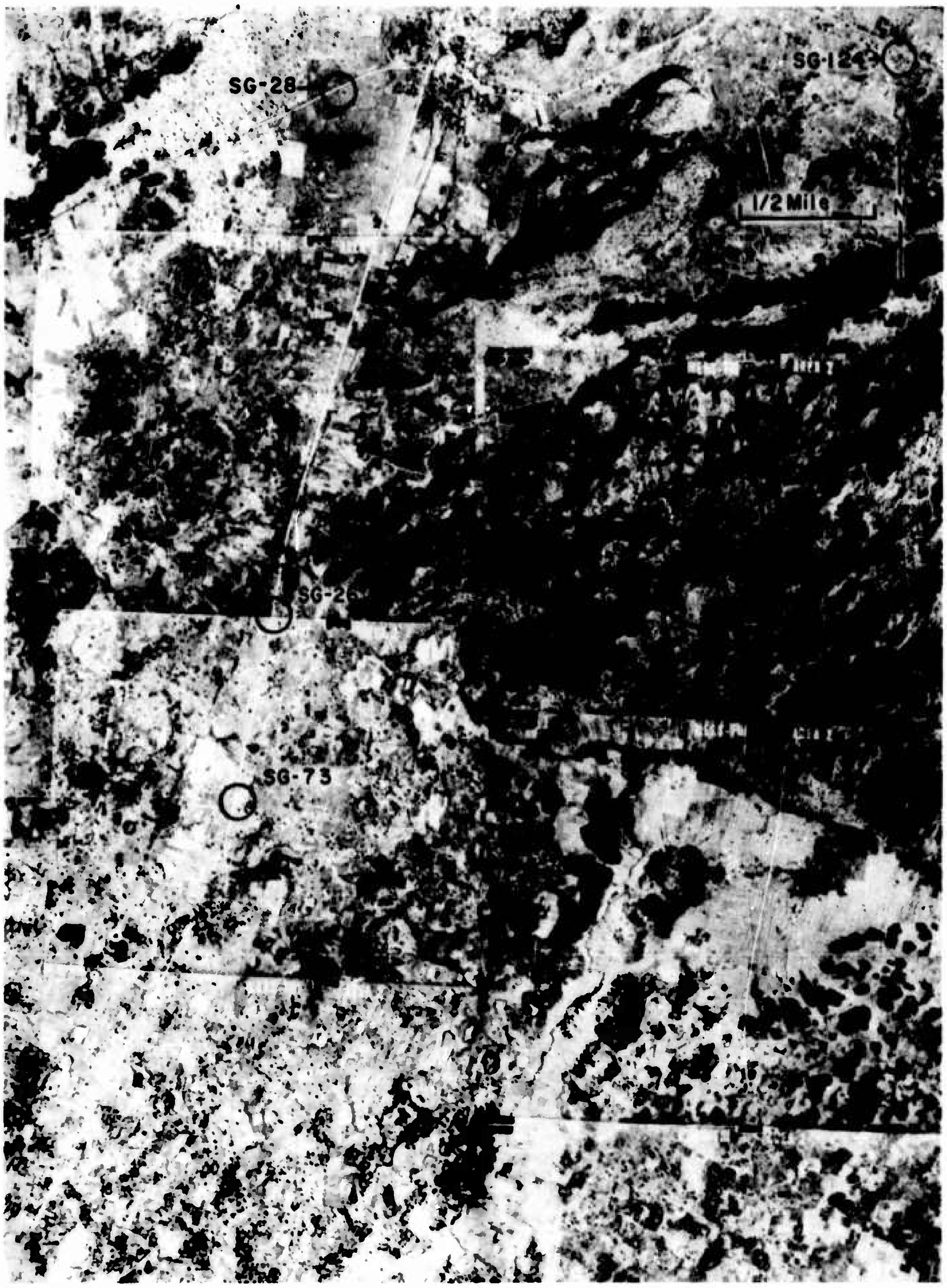



Fig. 104. Rolling karst terrain, sites SG-26, -28, -73, and -124
(January 1965)

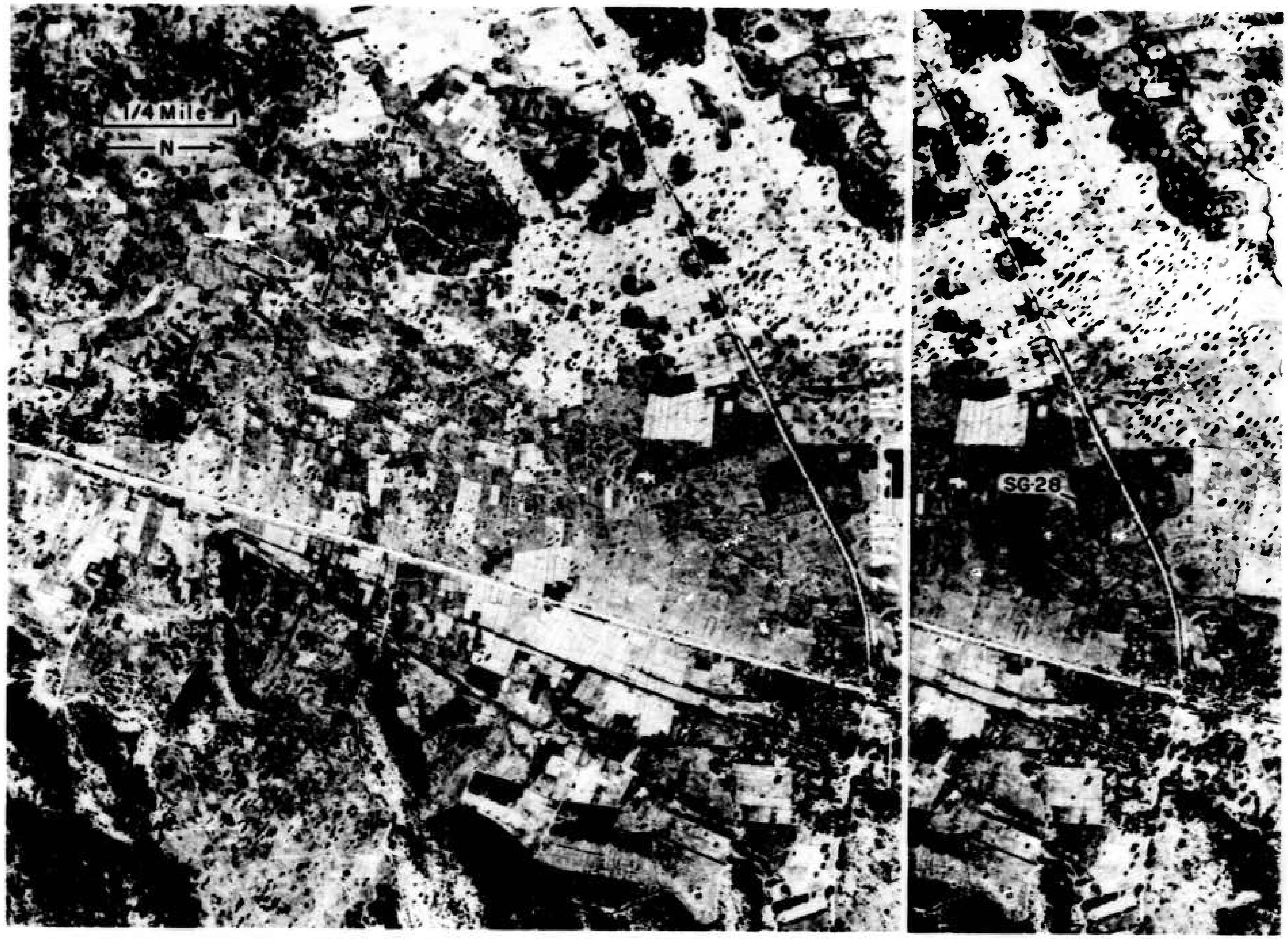



Fig. 105. Rolling karst terrain, site SG-28 (January 1965)

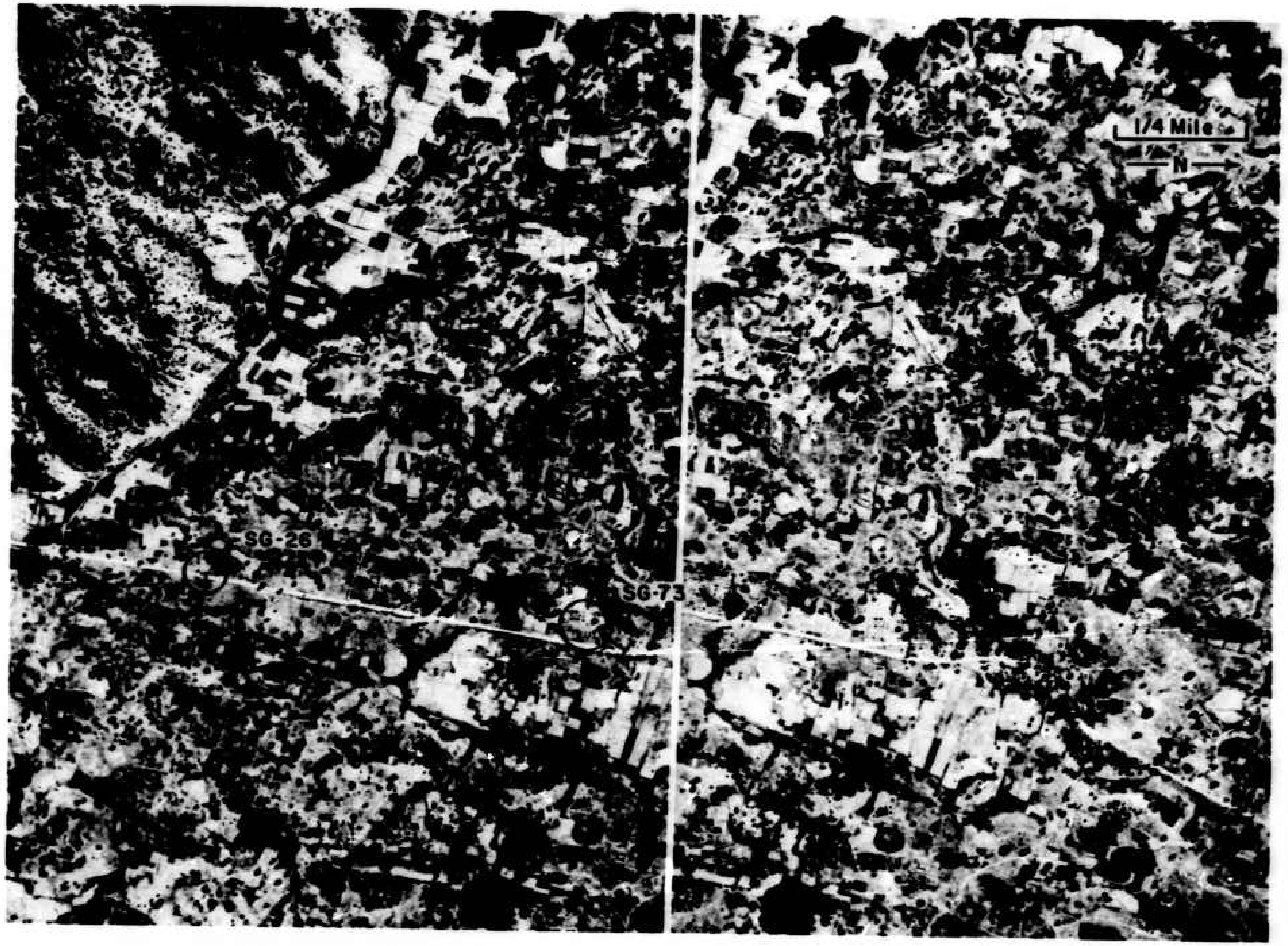



Fig. 106. Rolling karst terrain, sites SG-26 and -73 (January 1965)

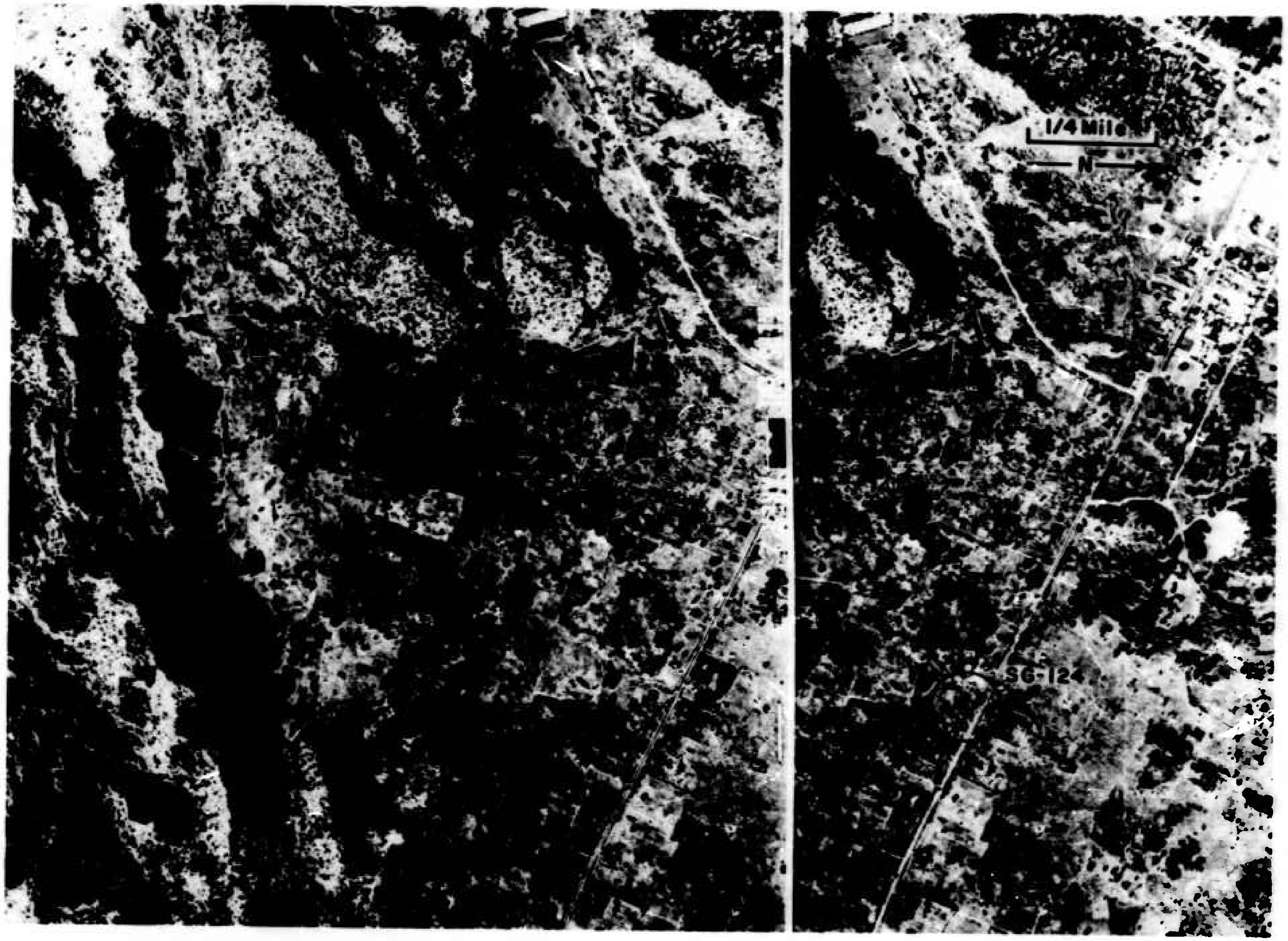


Fig. 107. Rolling karst terrain, site SG-124 (January 1965)

Fig. 108. Rolling karst terrain--view southeast toward mountain at site SG-28 (September 1964)

Fig. 109. Rolling karst terrain--view northeast across sinkhole toward mountain at site SG-73 (September 1964)

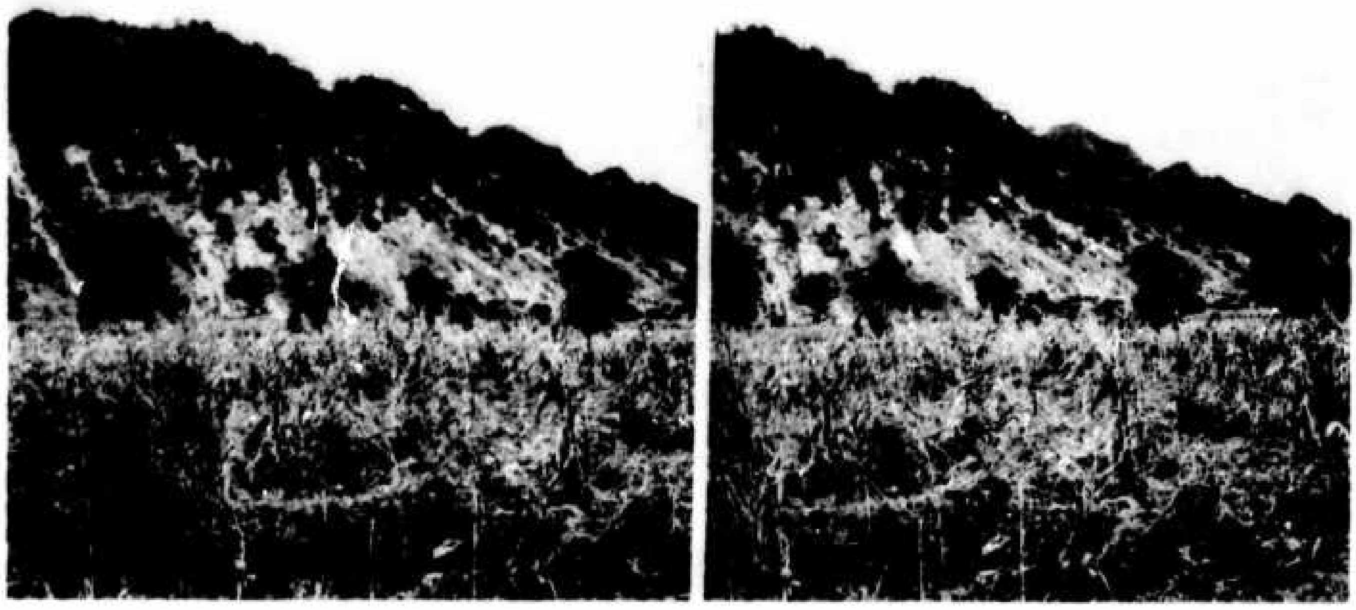


Fig. 110. Rolling karst terrain--view east over cornfield toward mountain, site SG-26 (September 1964)

Fig. 111. Rolling karst terrain--surface outcrops of limestone at site SG-124 (September 1964)


Fig. 112. Termite mounds in vicinity of Sara Buri, sites SG-47, -50, -51, -52, and -19 (January 1965)

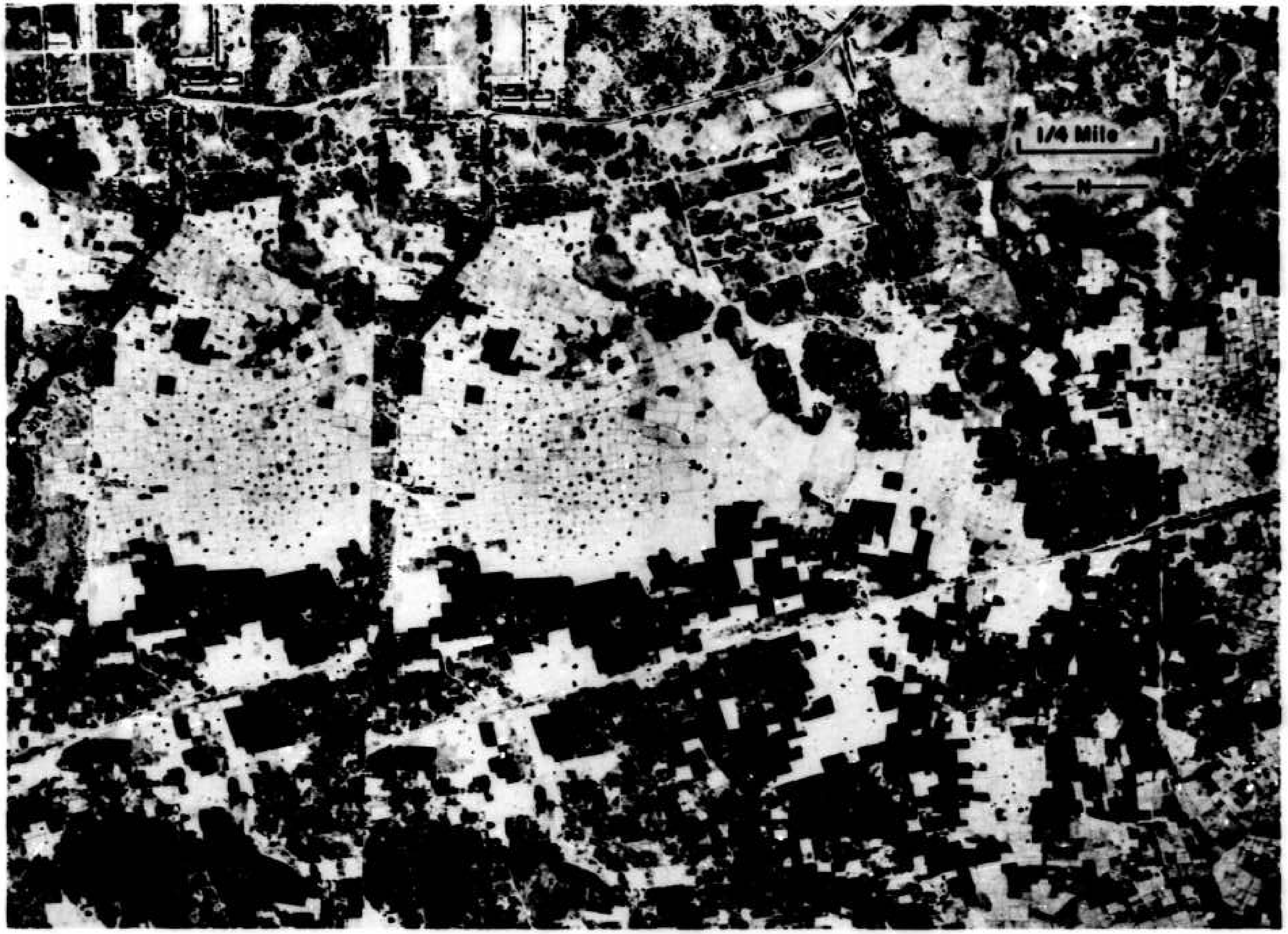



Fig. 113. Termite mounds without tree cover near Lop Buri, stereopair (January 1965)

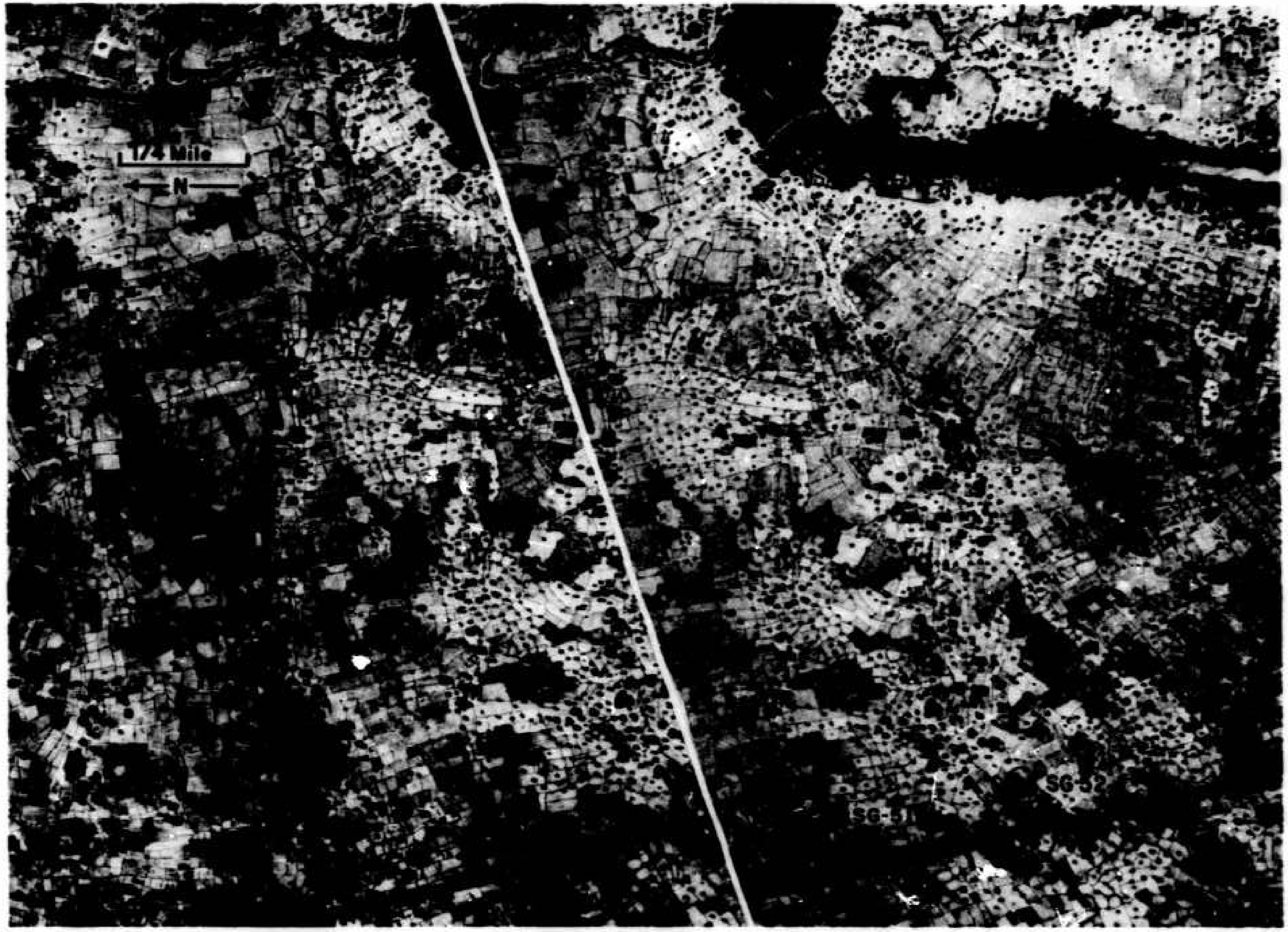



Fig. 114. Termite mounds in vicinity of sites SG-51 and -52, stereopair (January 1965)

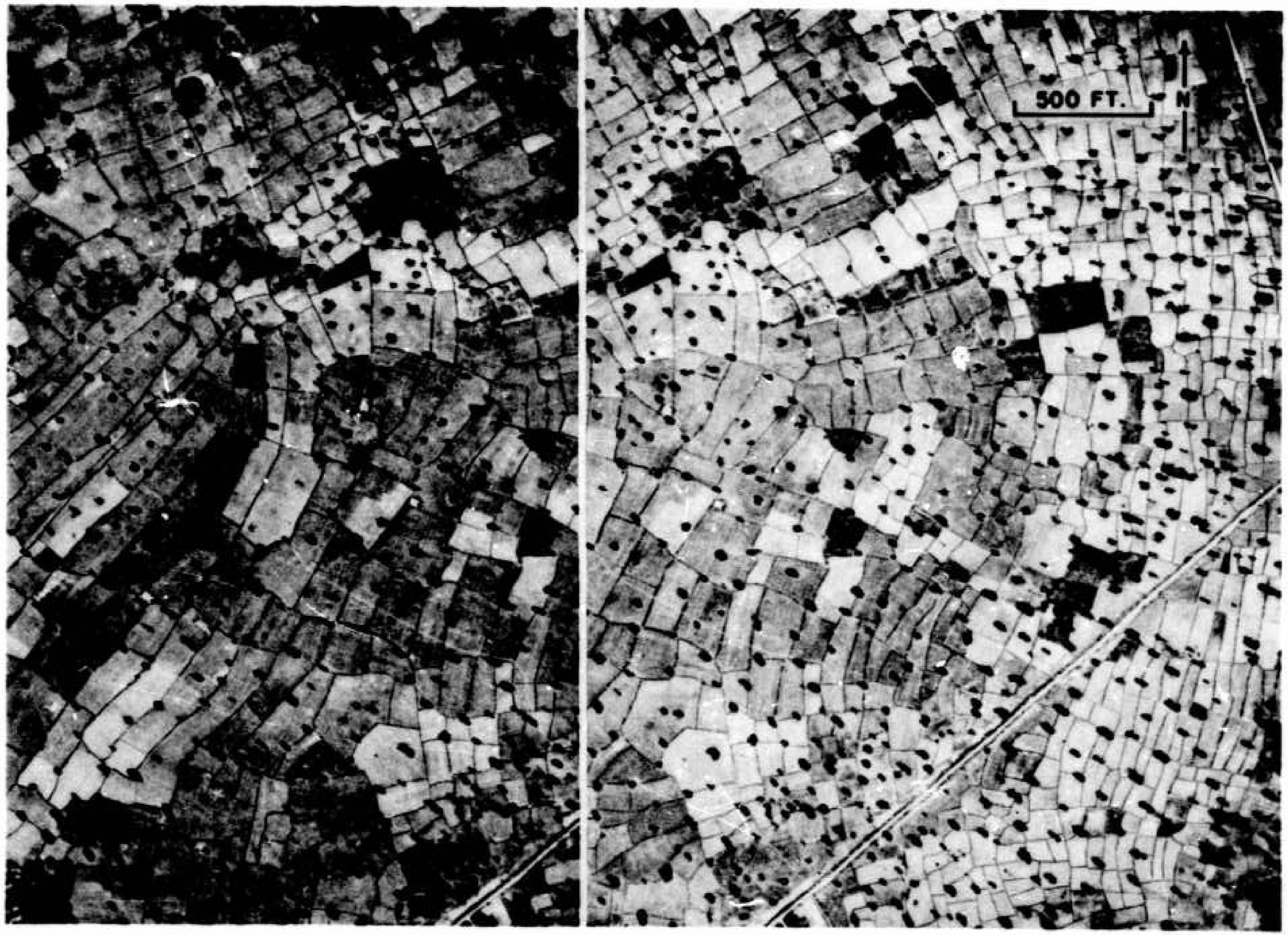



Fig. 115. Termite mounds--large-scale stereopair of dense mound area at Sara Buri (February 1965)


Fig. 116. Termite mounds--dense mounds at site SG-19
(January 1965 air photo; September 1964 ground photo)

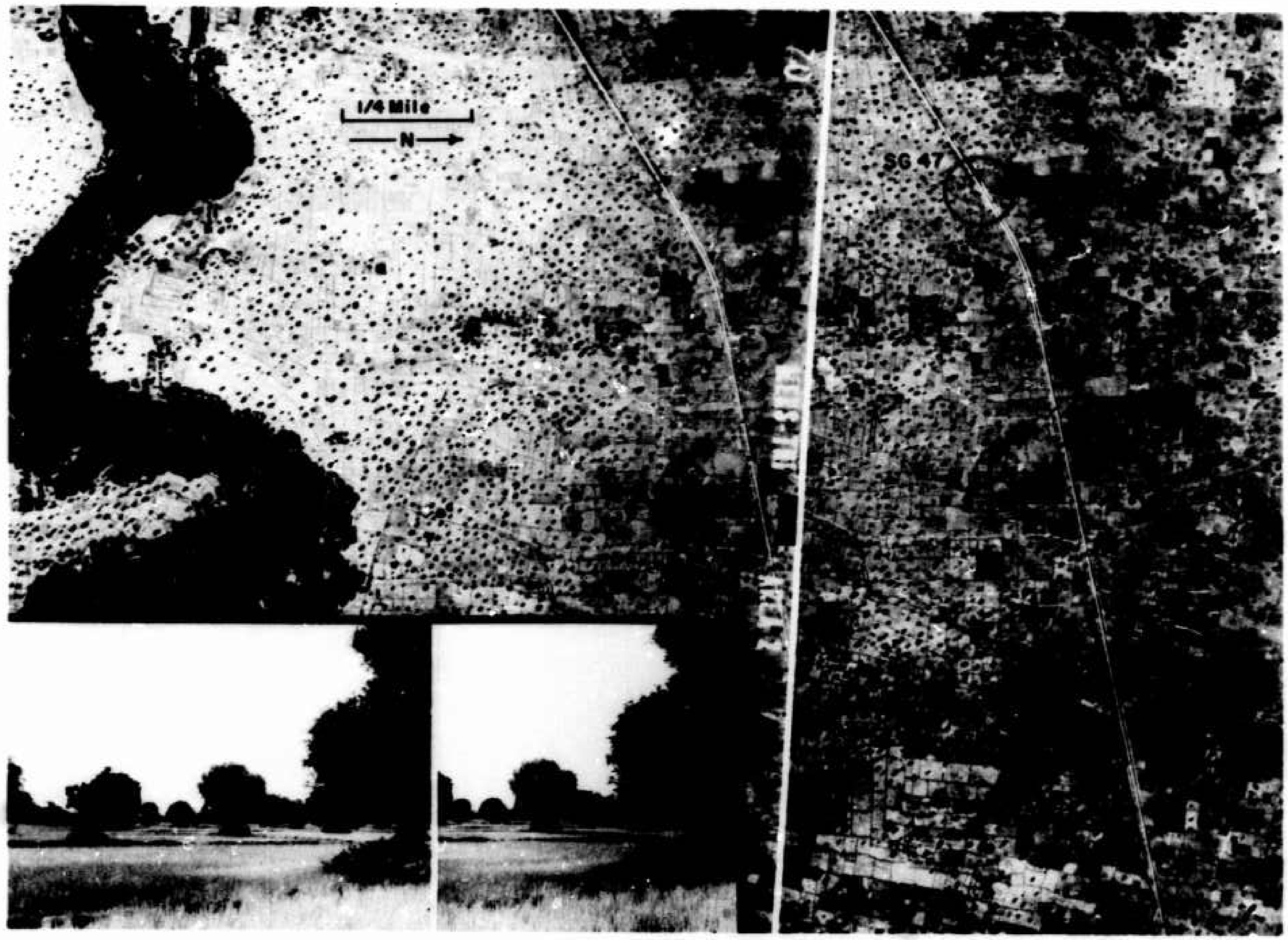



Fig. 117. Termite mounds--dense mounds on natural levee, site SG-47
(January 1965 air photo; September 1964 ground photo)

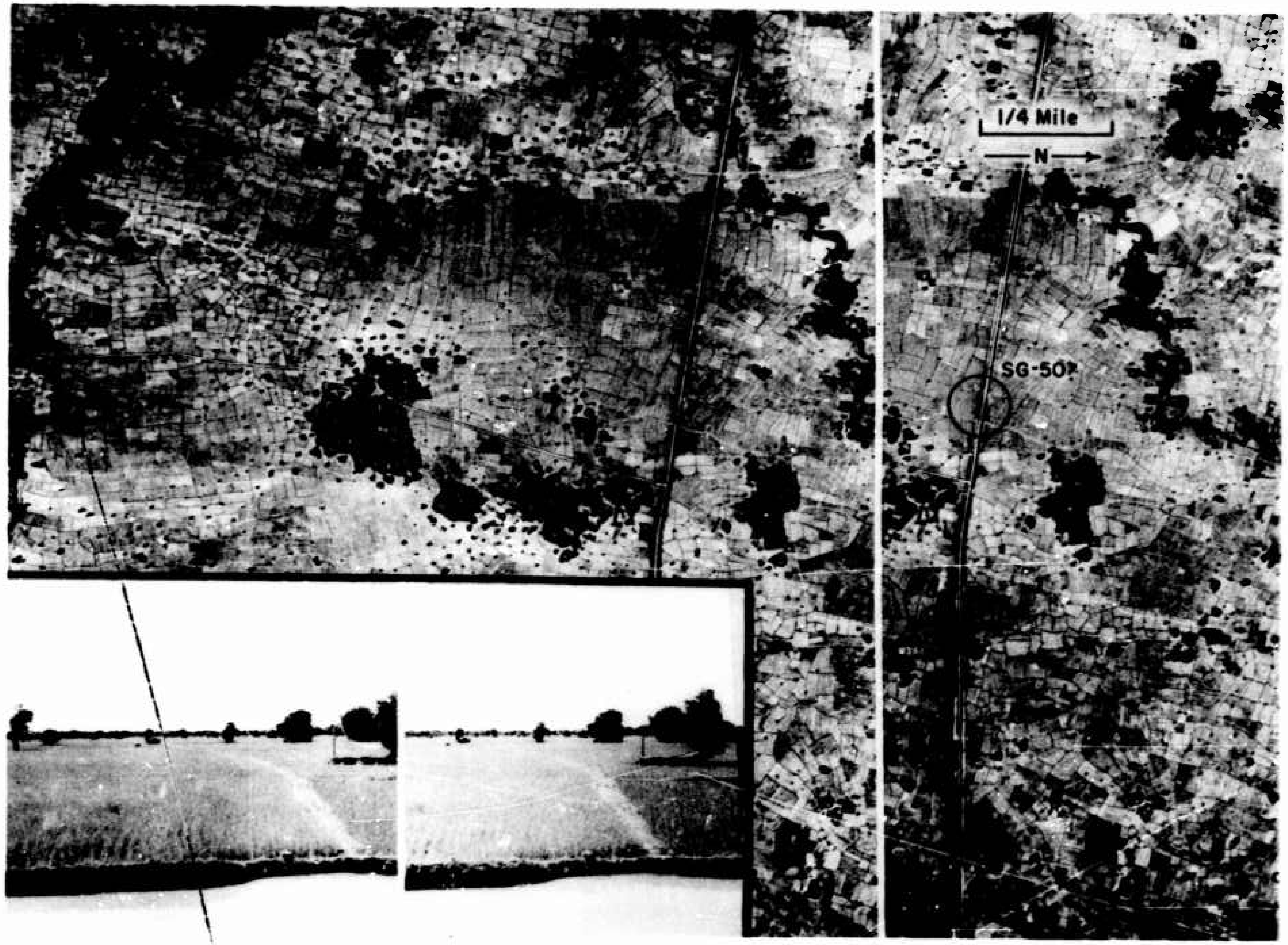



Fig. 118. Termite mounds--sparse mounds in low area, site SG-50
(January 1965 air photo; September 1964 ground photo)

Fig. 119. Termite mounds--view to southwest toward area of dense mounds at site SG-52 (September 1964)

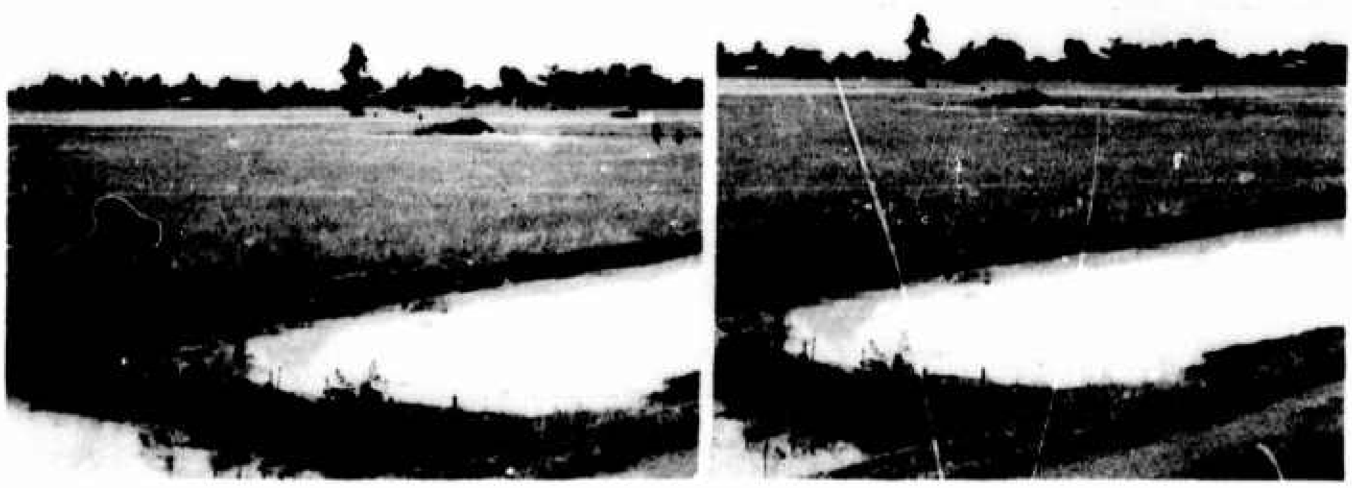


Fig. 120. Termite mounds--view to northwest toward area of sparse mounds at site SG-51 (September 1964)

VEGETATION

Table 4

Vegetation

Summary of Data

| Site | Location: Map Sheet* | Location: Grid Coordinates | Date of Sample | Average Stem Spacing ft | Average Stem Diameter in. | Average Plant Height ft | Photo Illustrations, Fig.: Air Photo | Photo Illustrations, Fig.: Ground Photo | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Rice Savanna | | | |
| VG-15 | 5154I | [illegible] | [illegible] | -- | -- | -- | -- | 134 | |
| VG-17 | 5154I | [illegible] | -- | -- | -- | -- | 132 | -- | |
| VG-[illegible] | 5155II | [illegible]70 | -- | -- | -- | -- | -- | 1[illegible] | |
| | | | | | | Tall Field Grass | | | |
| VG-1 AB | 5154II | 117[illegible] | -- | -- | -- | -- | -- | 132 | |
| VG-[illegible] | 5155II | [illegible]1[illegible] | -- | -- | -- | -- | -- | 136 | |
| VG-[illegible] | 5155IV | 147101 | -- | -- | -- | -- | -- | 133 | |
| VG-[illegible] | 5155IV | 1[illegible]1[illegible] | -- | -- | -- | -- | -- | 135 | |
| SG-105 | 5154II | [illegible]5870 | -- | -- | -- | -- | -- | 134 | |
| | | | | | | Shrub Savanna | | | |
| VG-50 | 5155III | 721374 | [illegible]-21-[illegible] | 17.8** | 16.3 ft† | 9.0 | -- | -- | |
| VG-54 | 5155IV | 73[illegible]73 | 9-21-[illegible] | 20.0** | 5.0 ft† | 3.0 | 138 | 139 | |
| VG-79 | 5155III | 153[illegible]74 | 10-10-64 | 1[illegible].[illegible]** | 3.0 ft† | 15.0 | -- | 140, 141 | Three species of shrubs, 2 with spines, underlain by short grass |
| | | | | | | Village Compound | | | |
| VG-10 | 5154III | [illegible]3993 | -- | -- | -- | -- | -- | 145 | |
| | | | | | | Rubber Plantation | | | |
| VG-50 | 5154I | [illegible]7[illegible] | 10-1[illegible]-[illegible] | 1[illegible].0 | 8.3 | 40.8 | -- | -- | |
| VG-95 | 5154I | [illegible]3984[illegible] | -- | -- | -- | -- | -- | 148 | |
| VG-96 | 5154I | [illegible]1[illegible]015 | 10-14-64 | 17.[illegible] | 1.5 | 15.8 | 146 | 151 | Trees about 3 years old; ground cover of legumes |
| VG-97 | 5154I | [illegible]138[illegible] | 10-1[illegible]-64 | 20.3 | 8.6 | 58.6 | 146, 147 | 14[illegible], 15[illegible] | Trees 8 years old |
| | | | | | | Semievergreen Forest | | | |
| VG-1 | 5154II | 117[illegible] | -- | -- | -- | -- | 153, 156 | 160 | |
| VG-[illegible] | 5154II | 118[illegible] | 9-4-6[illegible] | 13.6 | 3.6 | 25.0 | 153, 156 | -- | Shrubs dominated by 10- to 12-ft bamboo; frequent thorny lianas |
| VG-34 | 5155II | 03[illegible] | 9-17-64 | 1.0 | 1[illegible].0 | 5[illegible].[illegible] | -- | 157 | |
| | | | | | | Bamboo Forest | | | |
| VG-13 | 5154I | 07[illegible]067 | -- | -- | -- | -- | -- | 164 | |
| VG-55 | 5155IV | 75[illegible]47[illegible] | 9-21-64 | 10.[illegible]** | 1.[illegible] ft†† | 1[illegible].0 | 161 | 165 | |
| VG-60 | 5155IV | 83[illegible]49[illegible] | 9-26-64 | 13.7** | 3.6 ft†† | 25.[illegible] | 161, 162 | 163, 166 | |
| | | | | | | Evergreen Broadleaf Forest | | | |
| VG-[illegible] | 5154I | [illegible]586[illegible] | 10-14-64 | 9.3 | 7.7 | [illegible].8 | -- | 171, 172 | |
| | | | | | | Mangrove Swamp Forest | | | |
| VG-62 | 5154II | [illegible]7[illegible] | -- | -- | -- | -- | 174 | 175, 176 | |
| VG-83 | 5155IV | 039052 | -- | -- | -- | -- | -- | 178 | |
| | | | | | | Nipa Palm Swamp | | | |
| VG-70 | 5154I | 831030 | -- | -- | -- | -- | 179 | 181 | |

* Army Map Service, L708, 1:50,000.
** Spacing of clumps.
† Diameter of clump.
†† Diameter of stem clump.

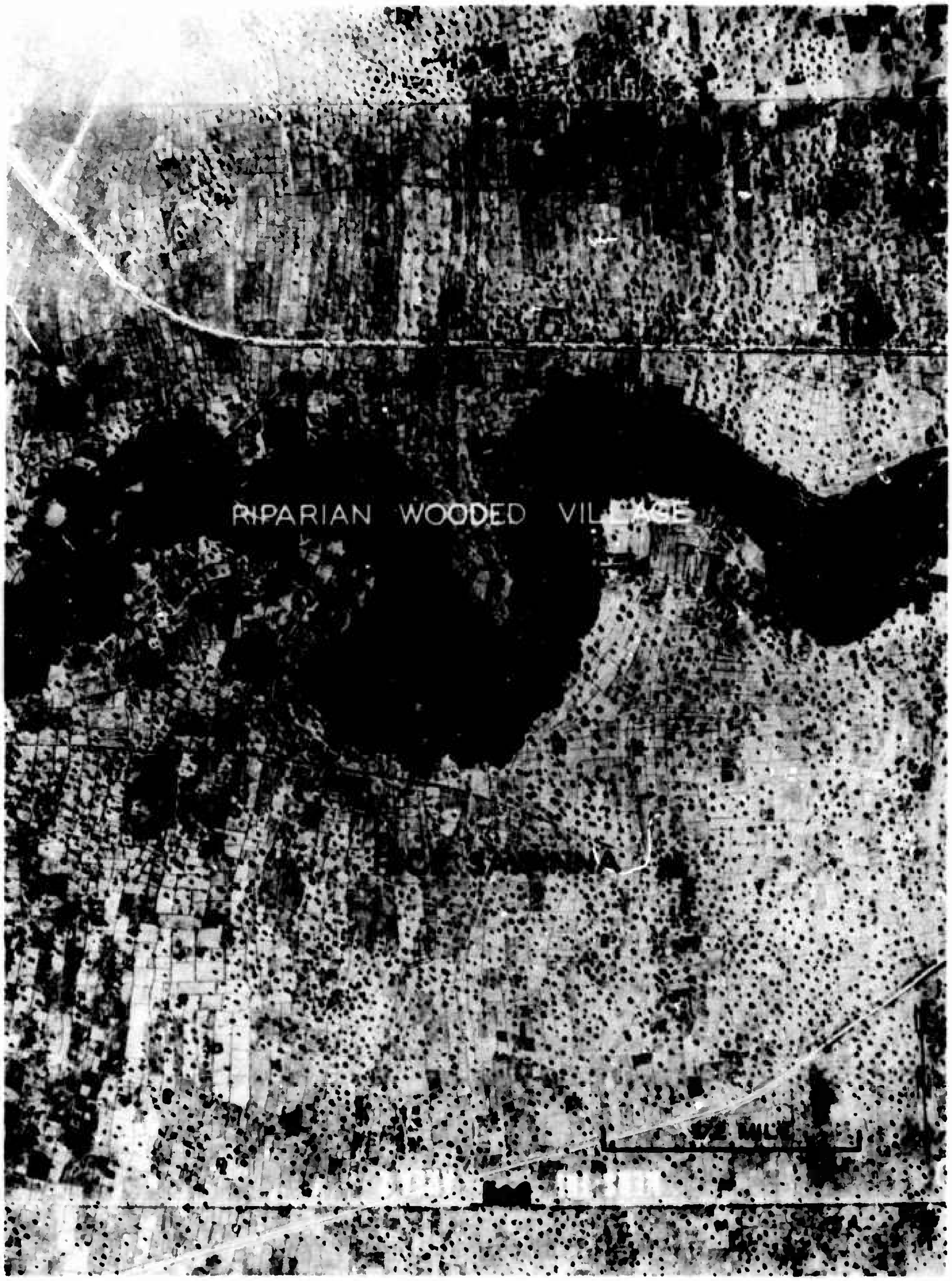



Fig. 121. Rice savanna along the Mae Nam Pa Sak west of Sara Buri. Configuration of rice paddies conforms to river levees (December 1964)

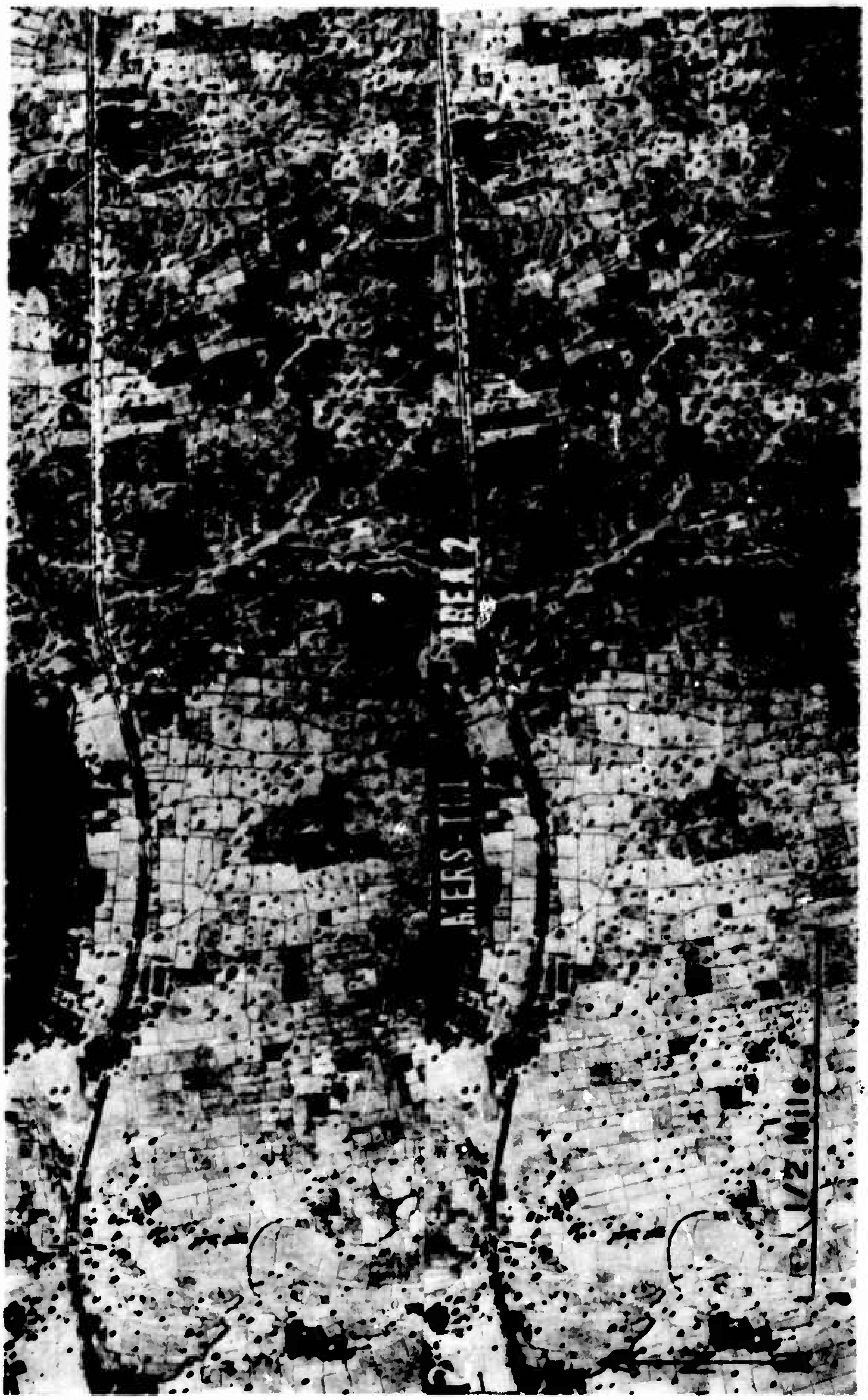



Fig. 122. Rice savanna west of Sara Buri near site VG-17 (stereopair).
Most trees are growing on termite mounds (December 1964)

Fig. 123. Rice savanna near site VG-42 (panoramic view). Trees and termite mounds cease in the distance on the Bangkok Plain (September 1964)

Fig. 124. Rice savanna--typical tree-covered termite mound at site VG-15. There are nine stems less than 1 in. and six stems from 3 to 10 in. on this mound (September 1964)


Fig. 125. Rong agriculture--air photo of Amphoe Nong Khae, south of Sara Buri, showing rong development (February 1953)

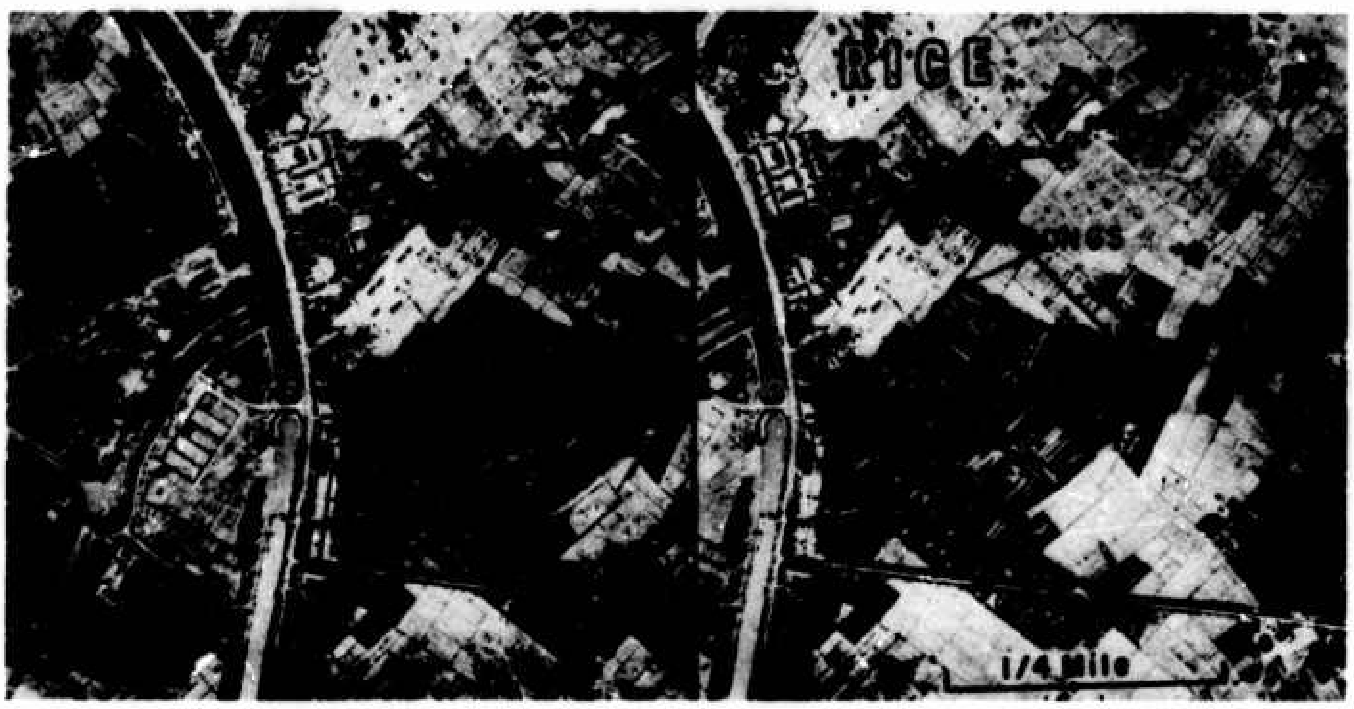



Fig. 126. Rong agriculture--stereopair of rongs with vegetable crops at Amphoe Nong Khae (December 1964)

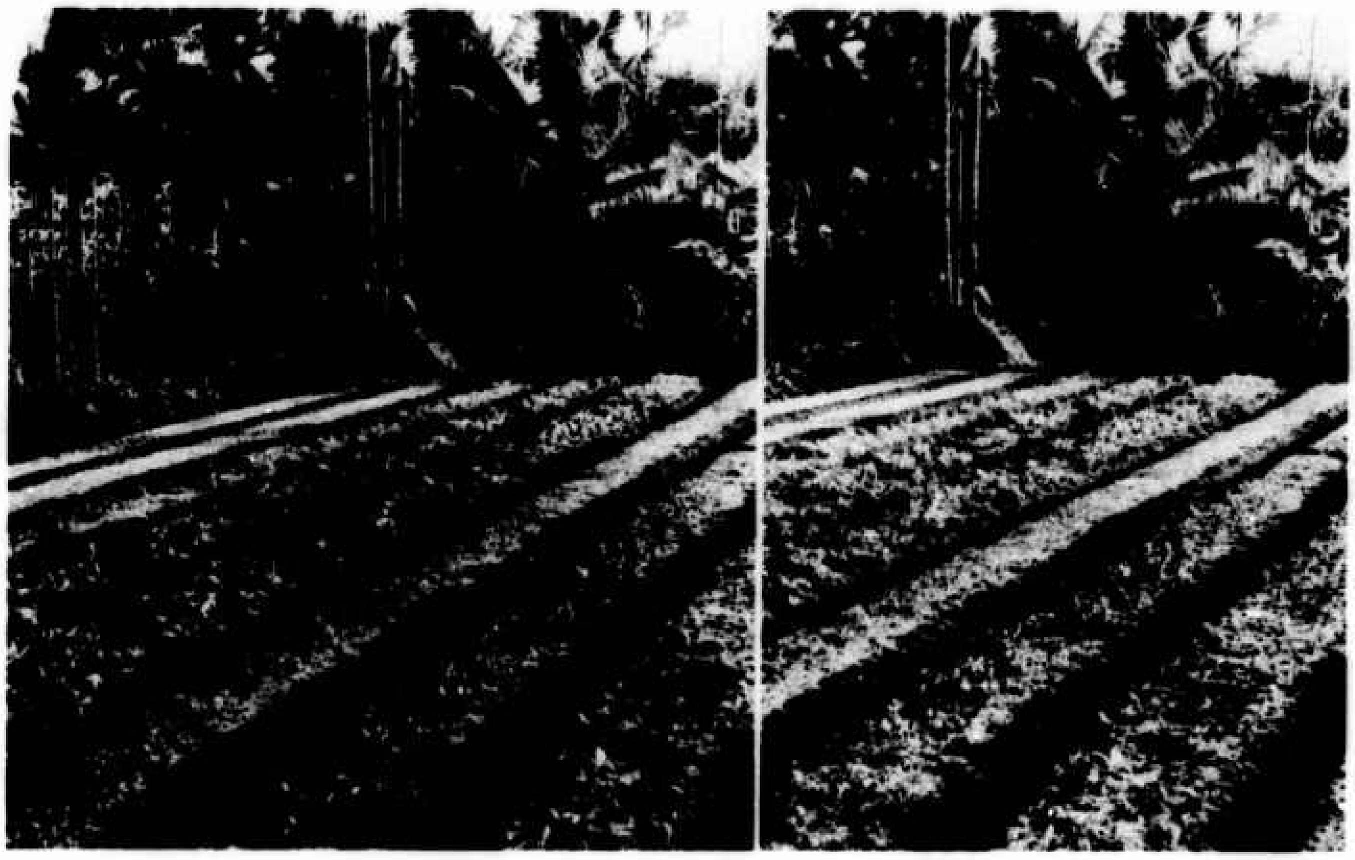


Fig. 127. Rong agriculture--vegetable crops growing on rongs within the town of Chanthaburi


Fig. 128. Tall field crops--area being cleared for new agriculture northeast of Amphoe Phra Phutthabat, Lop Buri area (January 1953)

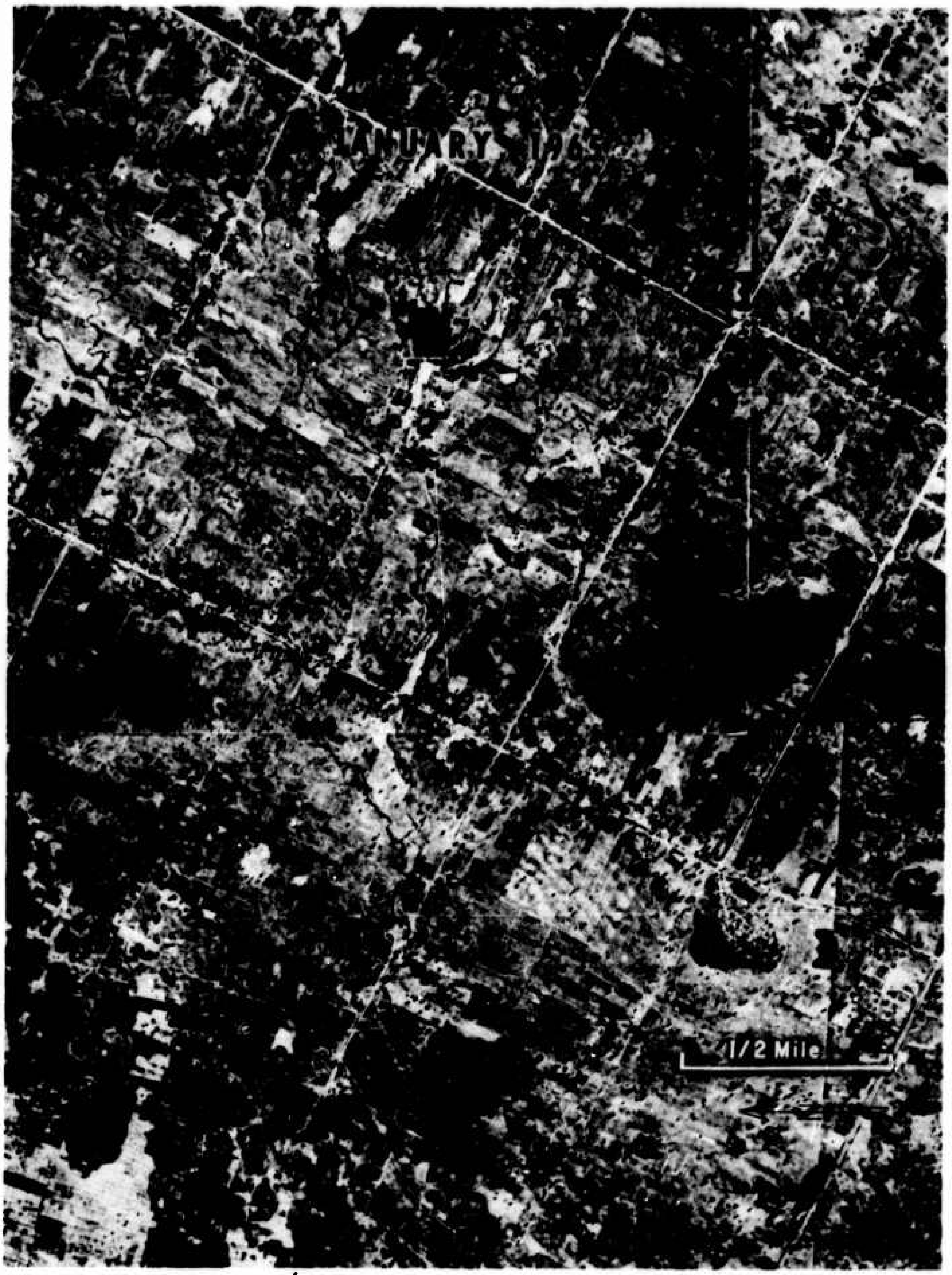



Fig. 129. Tall field crops--new agricultural land in same area as fig. 128, 12 years later (January 1965)

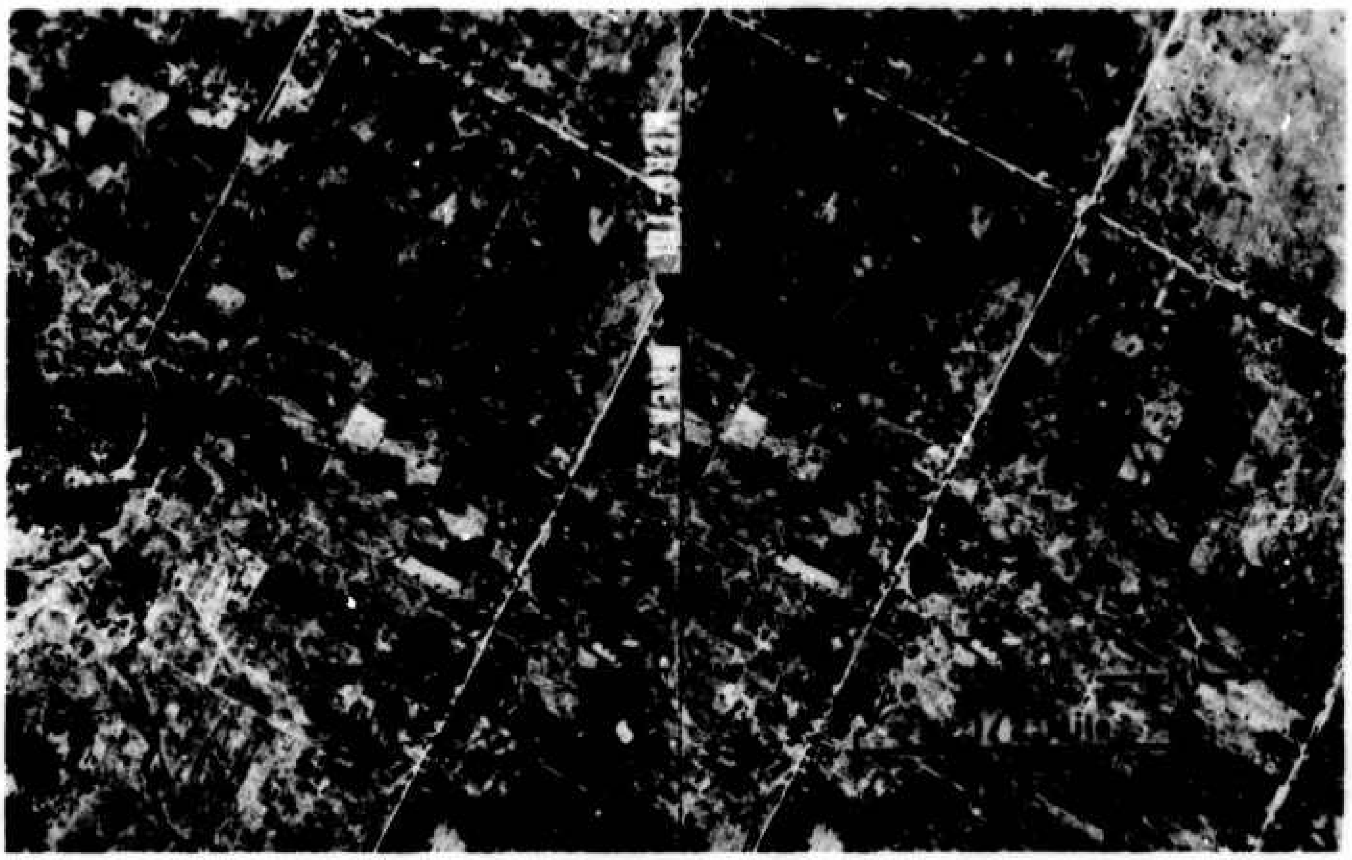


Fig. 130. Tall field crops--new corn farms northeast of Amphoe Phra Phutthabat, Lop Buri area (December 1964)

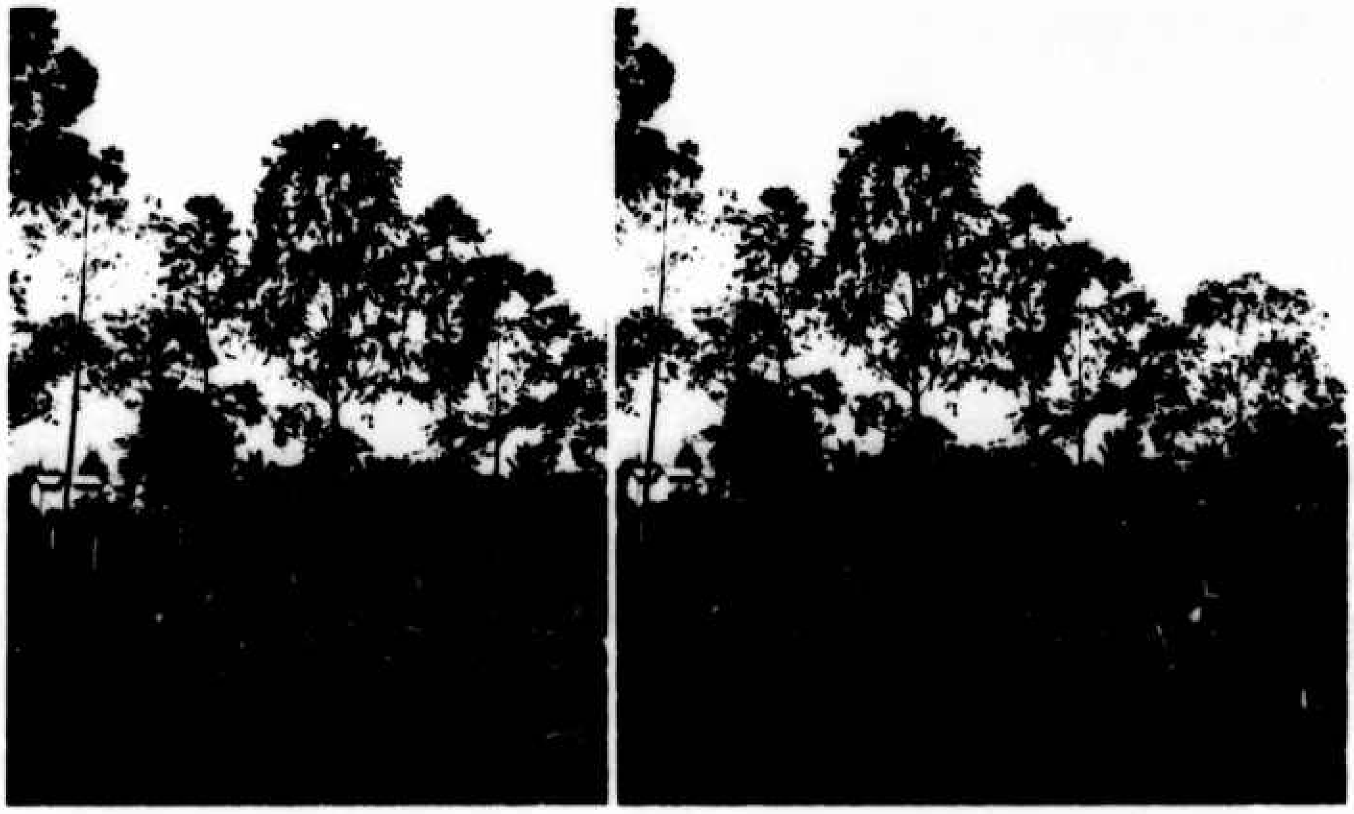


Fig. 131. Tall field crops--tobacco growing east of Chiang Mai. Note drying sheds in background (September 1964)

Fig. 132. Tall field crops--corn field along the Friendship Highway at site VG-1AB (September 1964)

Fig. 133. Tall field crops--sugar cane on new farm at site VG-85 northwest of Chanthaburi (October 1964)

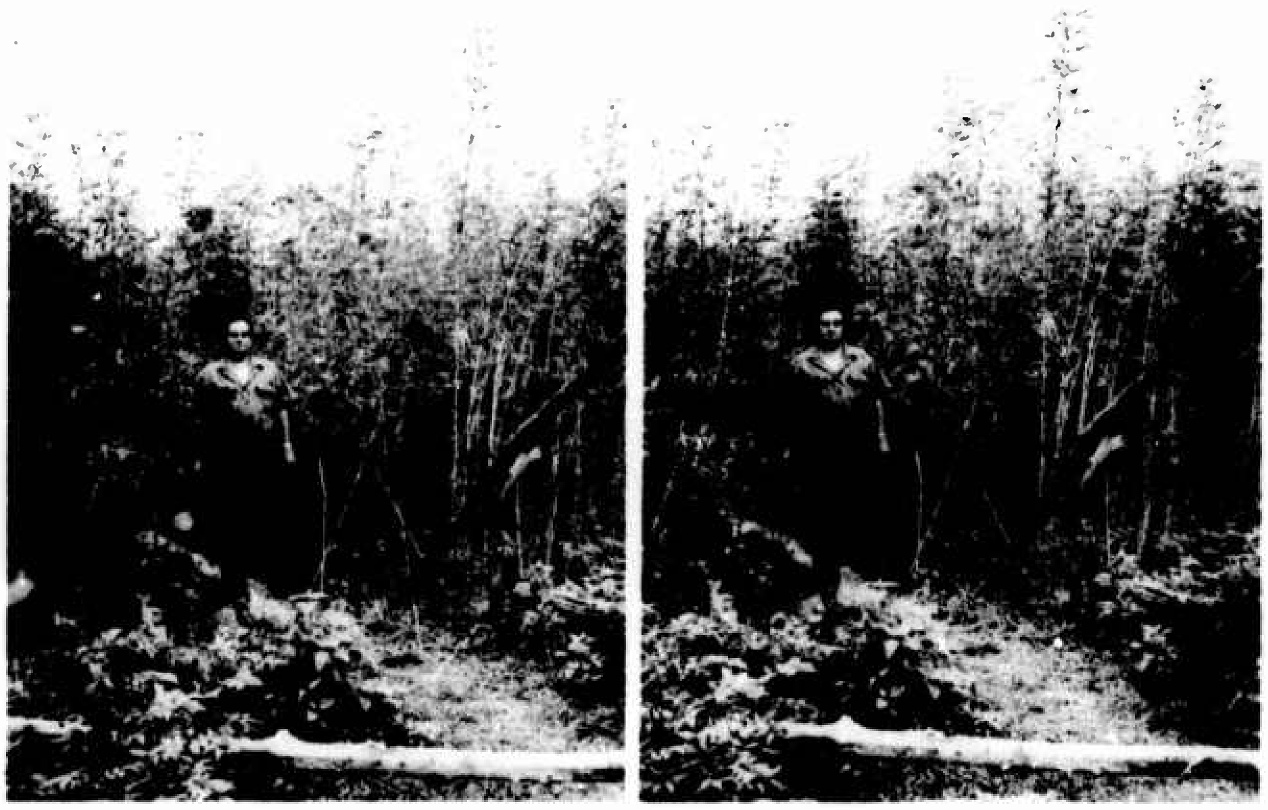


Fig. 134. Tall field crops--jute field for fiber production at site SG-105 east of Khon Kaen (September 1964)

Fig. 135. Tall field crops--cassava for production of tapioca at site VG-86 northeast of Chanthaburi (October 1964)

Fig. 136. Tall field crops--tall tropical grass at site VG-24 (October 1964)

Fig. 137. Shrub savanna near the coast, 28 miles south of Hua Hin, Pran Buri area (March 1955)


Fig. 138. Shrub savanna--stereopair of low shrub savanna and cattle pasture at site VG-54 (February 1953)

Fig. 139. Shrub savanna--ground photo of low shrub savanna and short grass pasture at site VG-54 (September 1964)

Fig. 140. Shrub savanna--thorny shrubs and short trees with sparse grass ground cover at site VG-79 (October 1964)

Fig. 141. Shrub savanna (low) west of site VG-79 in Chanthaburi area (January 1965)


Fig. 142. Village compounds scattered in rice paddy savanna southwest of Sara Buri (December 1964)

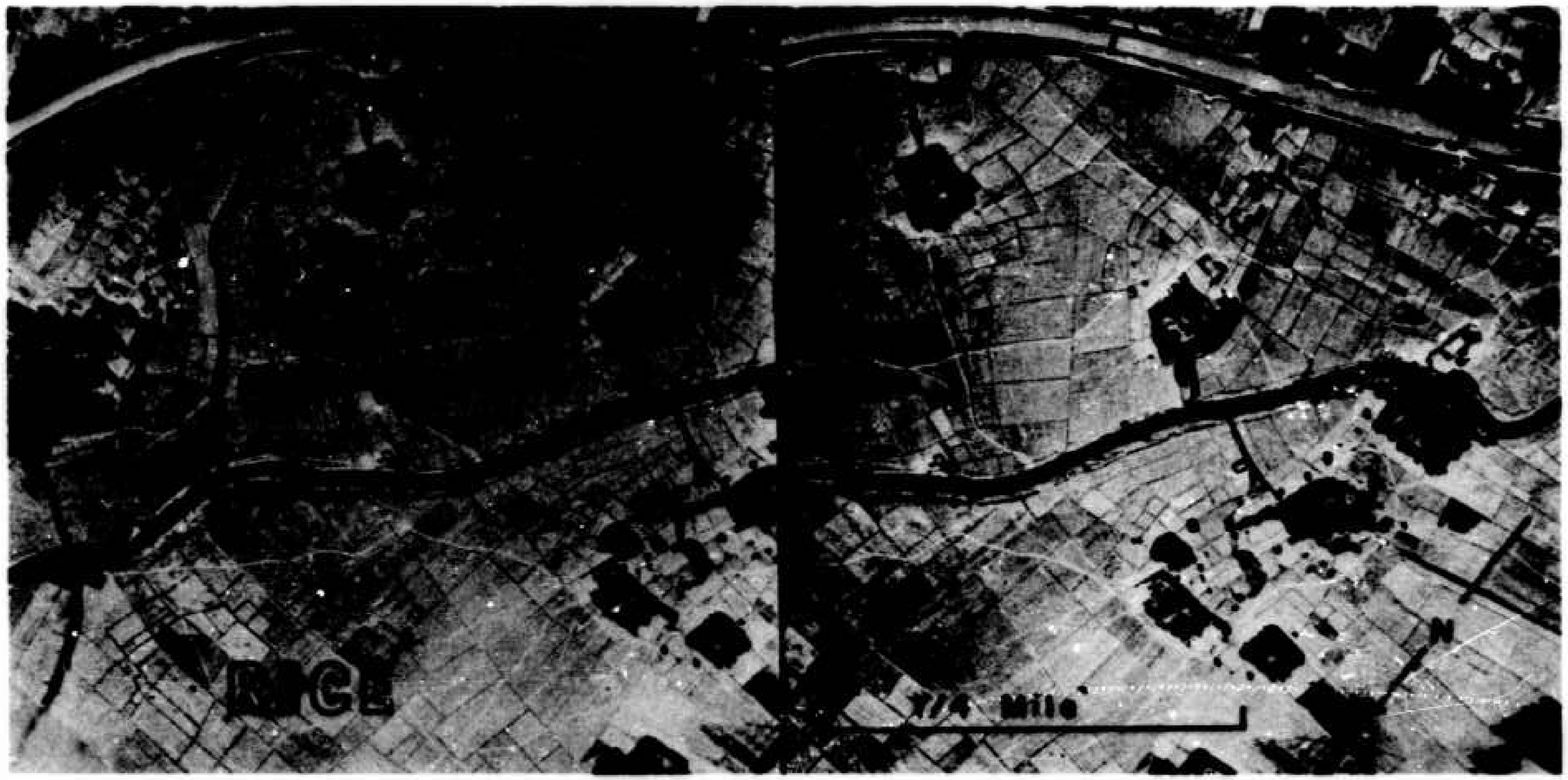



Fig. 143. Village compounds with typical box-shaped vegetation configuration near Amphoe Nong Khae south of Sara Buri (December 1964)

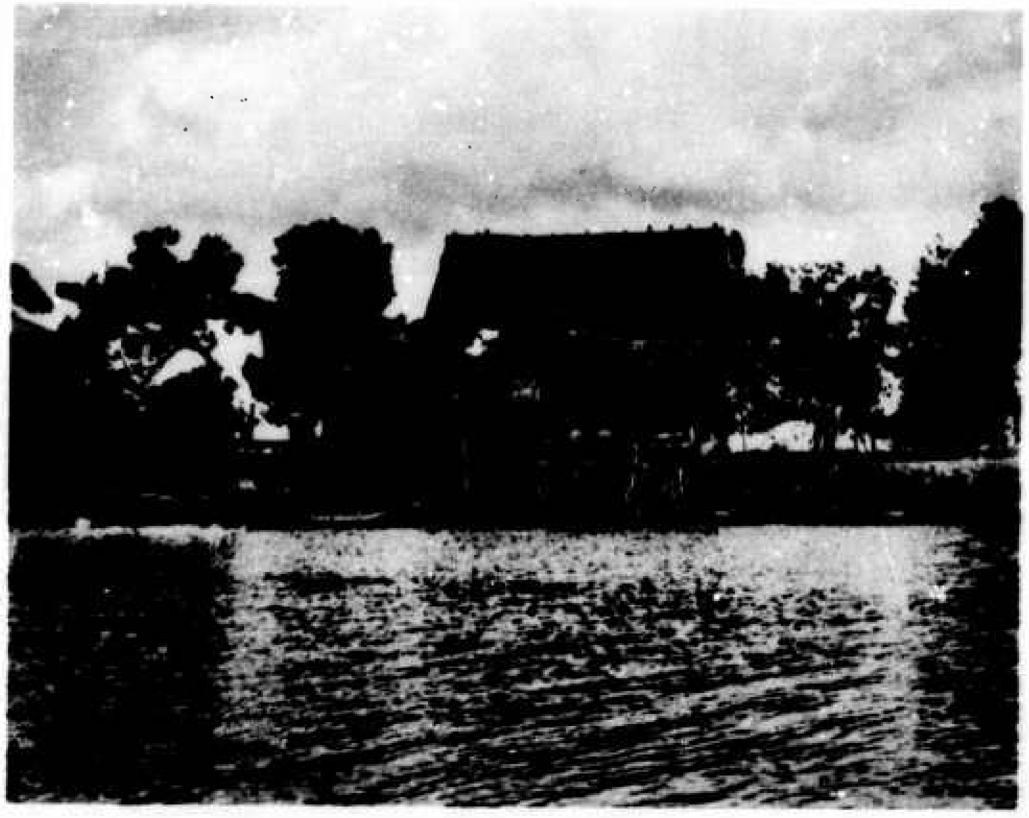


Fig. 144. Village compound--typical residence bordering brackish stream south of Chanthaburi (October 1964)

Fig. 145. Village compound at site VG-10 north of Ayutthaya (September 1964)

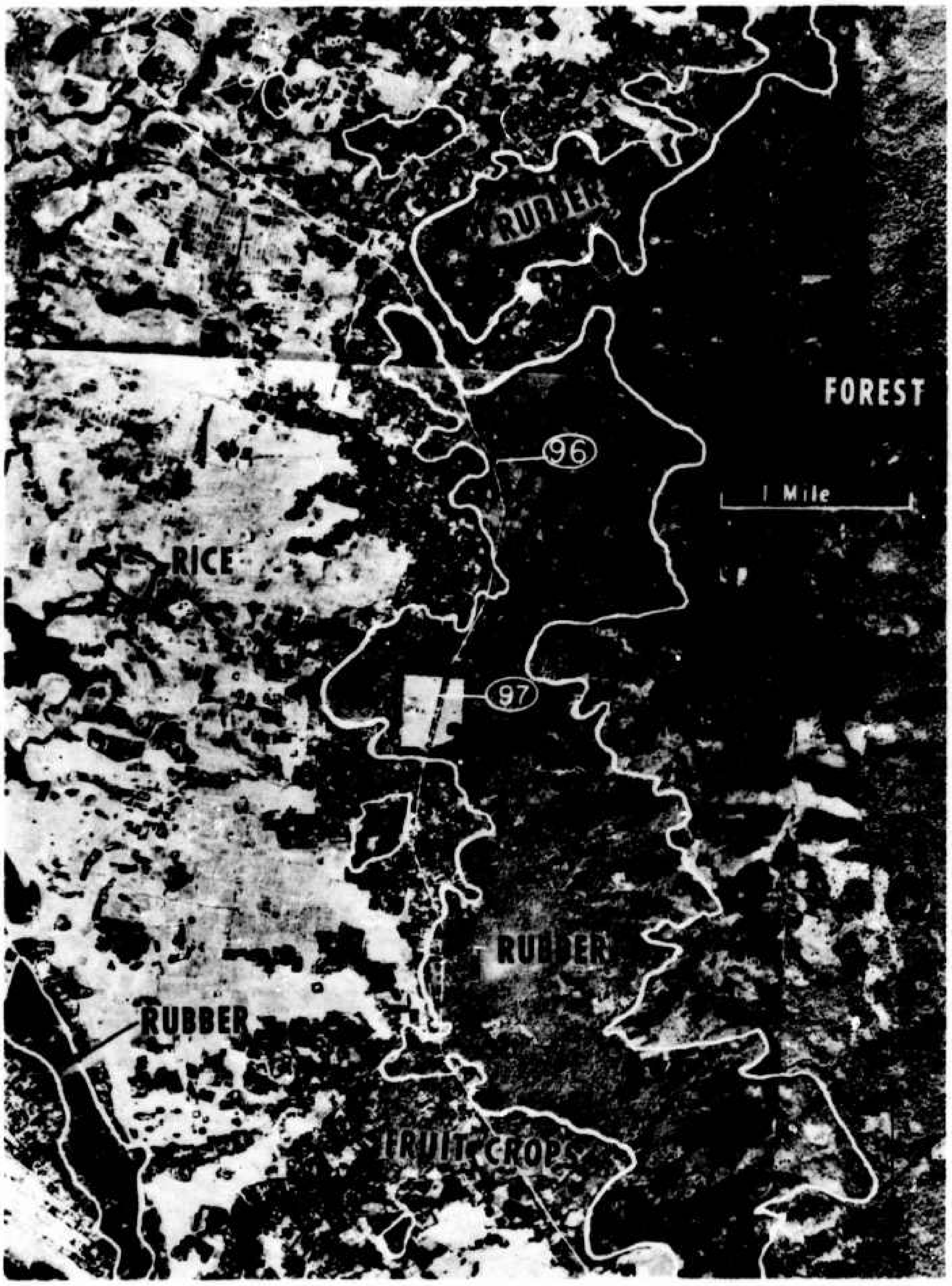



Fig. 146. Rubber plantations on lower slopes southeast of Chanthaburi (February 1953)

Fig. 147. Rubber plantations on deep soil near site VG-97, which is shown in fig. 146 (February 1953)

Fig. 148. Rubber plantation--tap root system of a rubber tree in deep soil near site VG-95 southeast of Chanthaburi (October 1964)

Fig. 149. Rubber plantation (commercial) at site VG-97 southeast of Chanthaburi (October 1964)

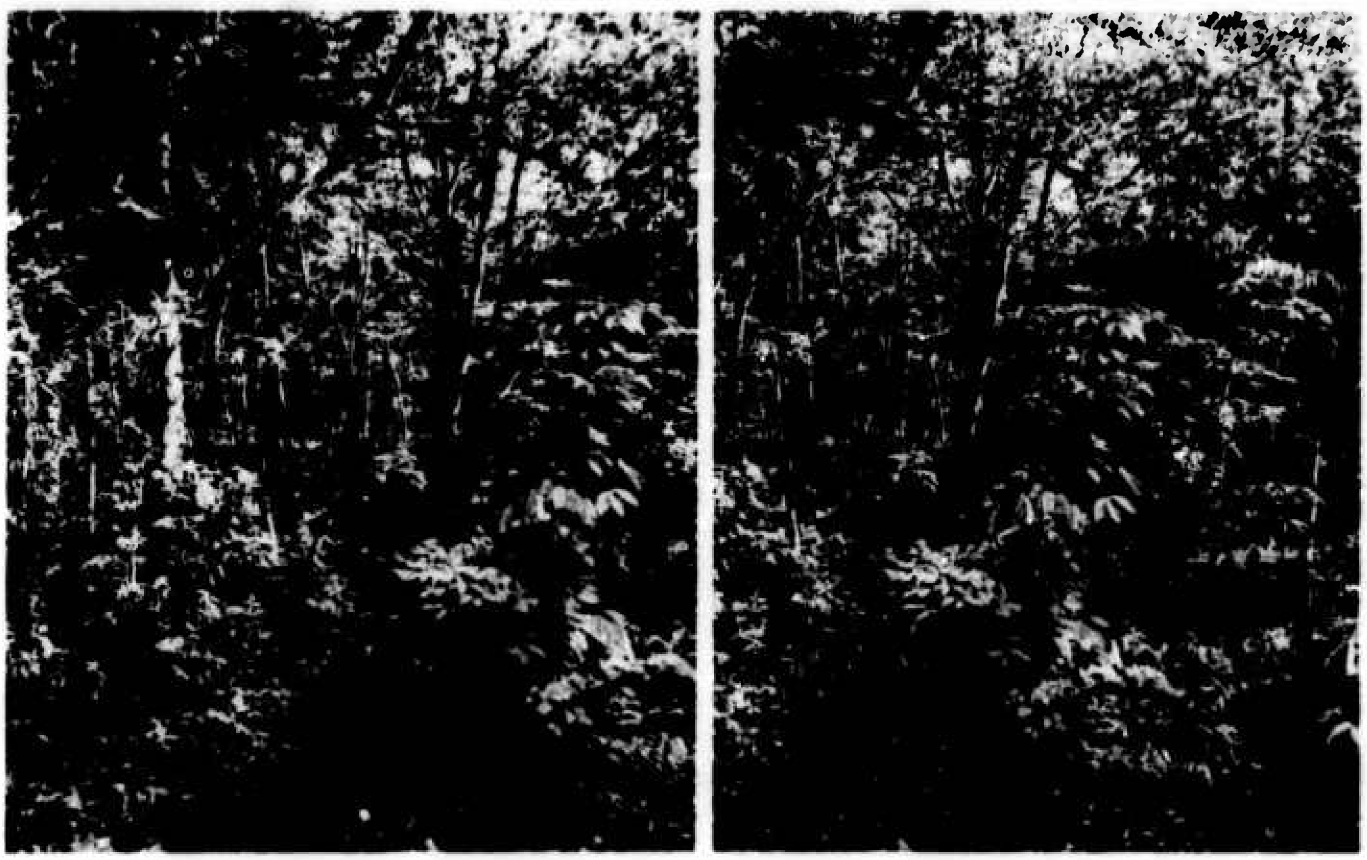


Fig. 150. Rubber plantation with undergrowth before brushing (October 1964)

Fig. 151. Rubber plantation--young rubber tree plants with leguminous ground cover at site VG-96, which is shown in fig. 146 (October 1964)

Fig. 152. Rubber plantation--rubber tree tapped for latex, site VG-97 (October 1964)


Fig. 153. Semievergreen forest southeast of Sara Buri
(December 1964)

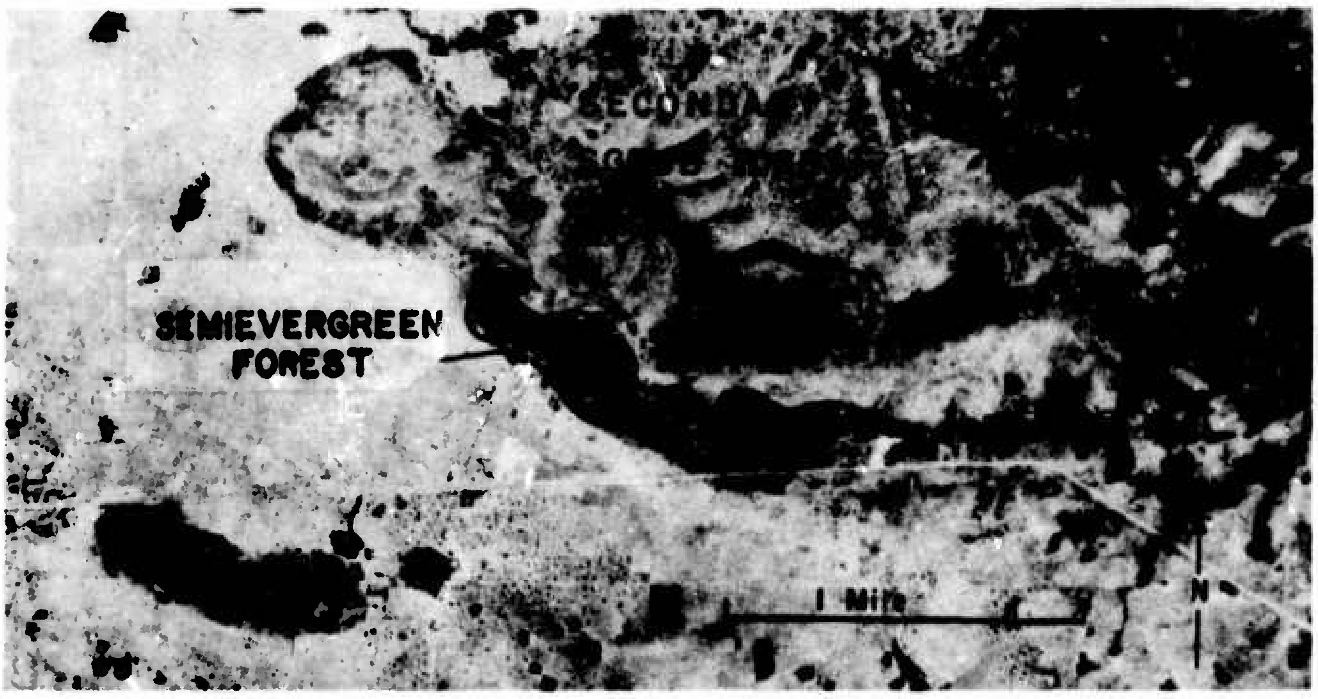



Fig. 154. Semievergreen forest remnant and secondary scrub forest east of Ban Hin Kong (February 1953)

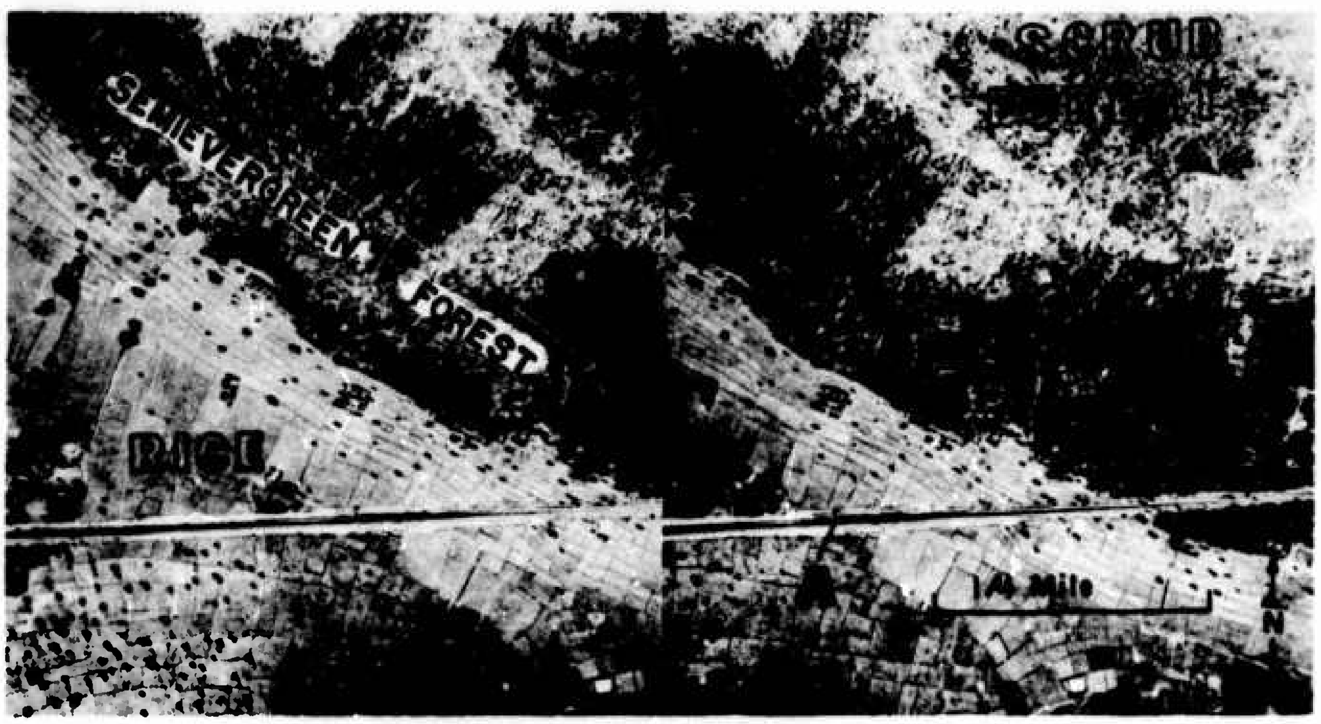



Fig. 155. Semievergreen forest remnant shown in fig. 154, stereopair (December 1964)

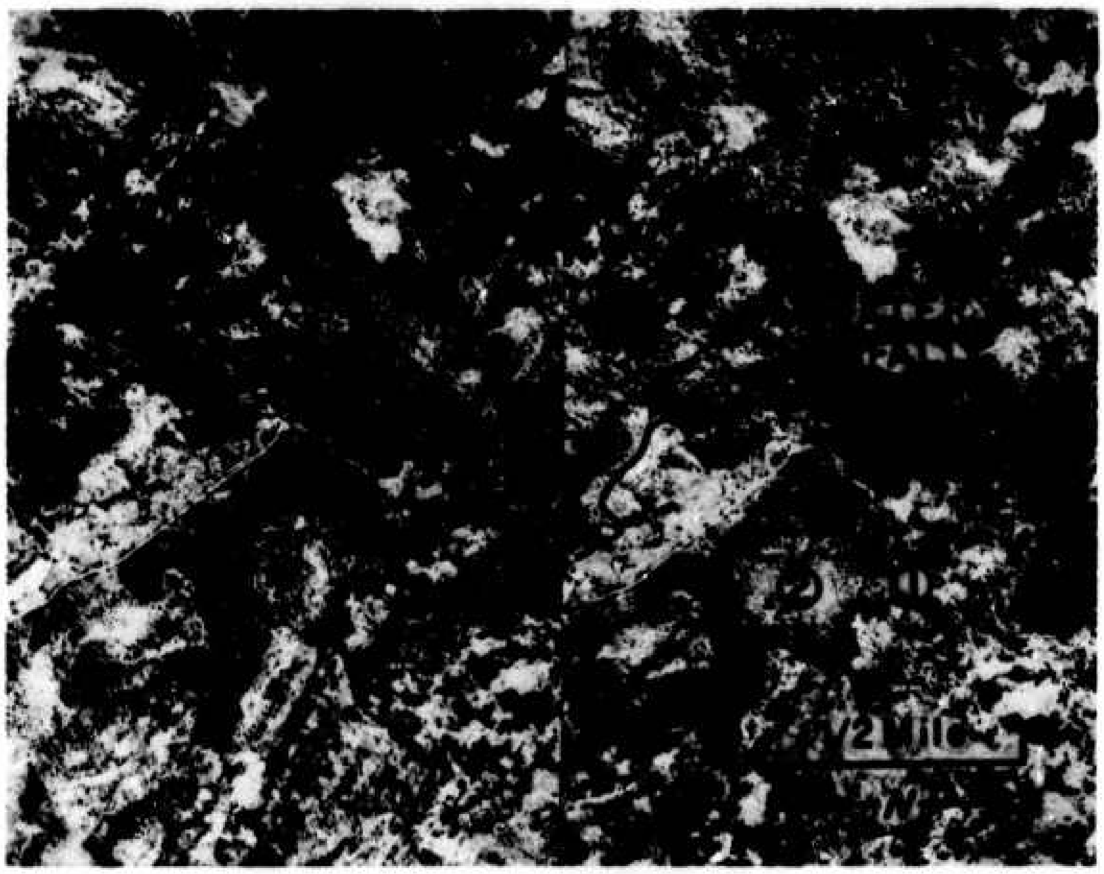


Fig. 156. Semievergreen forest southeast of Sara Buri at sites VG-1 and -2, stereopair (December 1964)

Fig. 157. Semievergreen forest remnant north of Sara Buri at site VG-34 (September 1964)

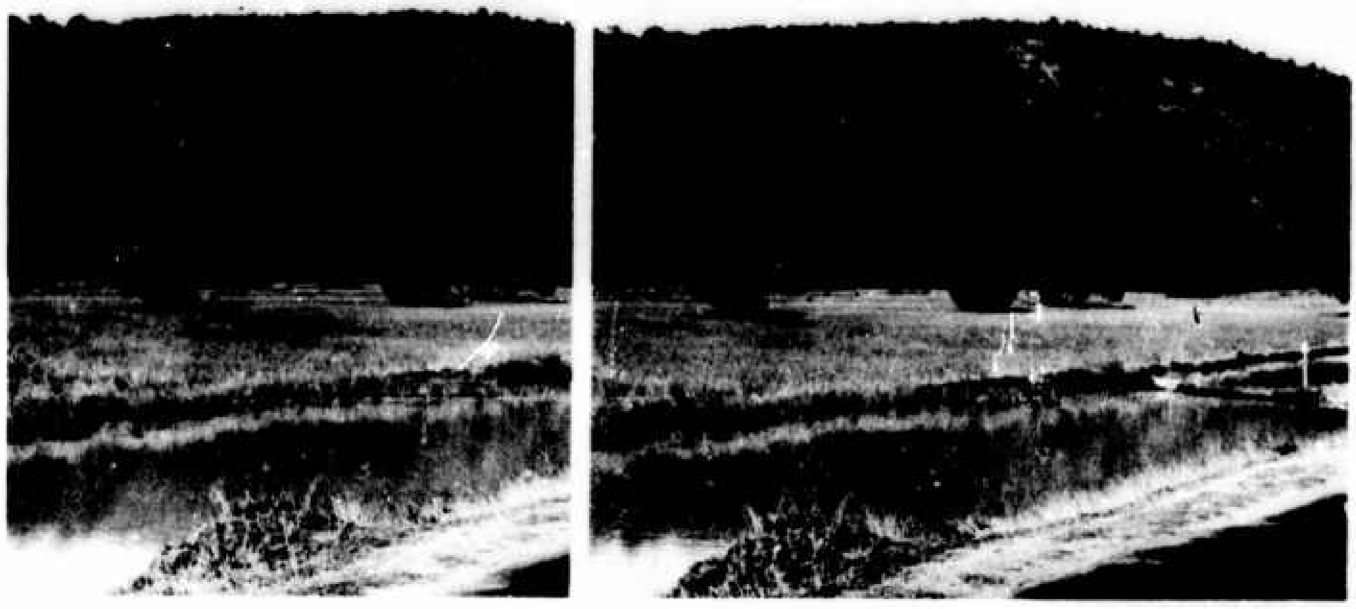


Fig. 158. Semievergreen forest east of Ban Hin Kong. Photo was taken from site A shown in fig. 155 (September 1964)

Fig. 159. Semievergreen forest--cutover evergreen forest slope, now mostly grass and bamboo

Fig. 160. Semievergreen forest--secondary scrub forest at site VG-1 southeast of Sara Buri (September 1964)

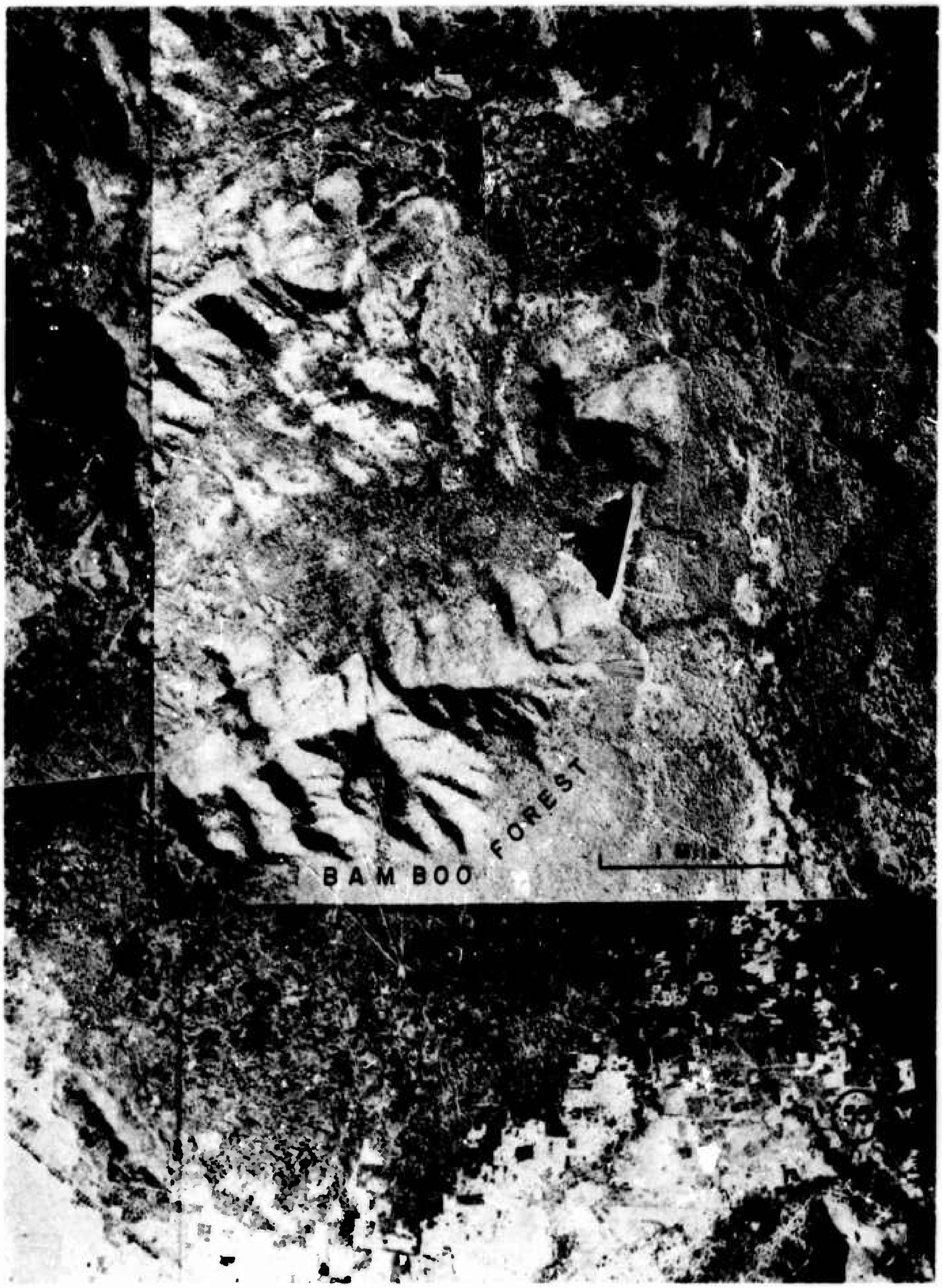



Fig. 161. Bamboo forest interspersed with low trees northeast of Lop Buri (December 1953)

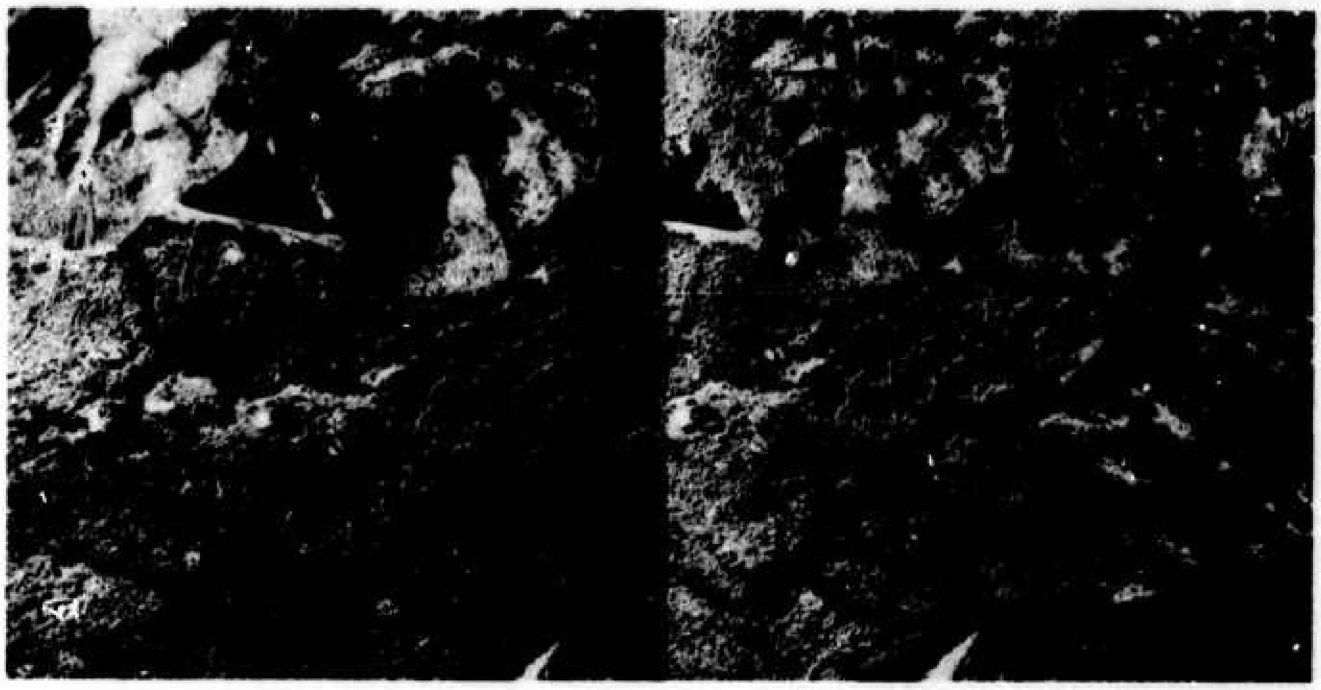


Fig. 162. Bamboo forest on slopes at site VG-60, stereopair (December 1953)

Fig. 163. Bamboo forest--bamboo clumps at site VG-60; tall thorny species to left, nonthorny species on right (September 1964)

Fig. 164. Bamboo forest--short bamboo clump at site VG-13 (September 1964)

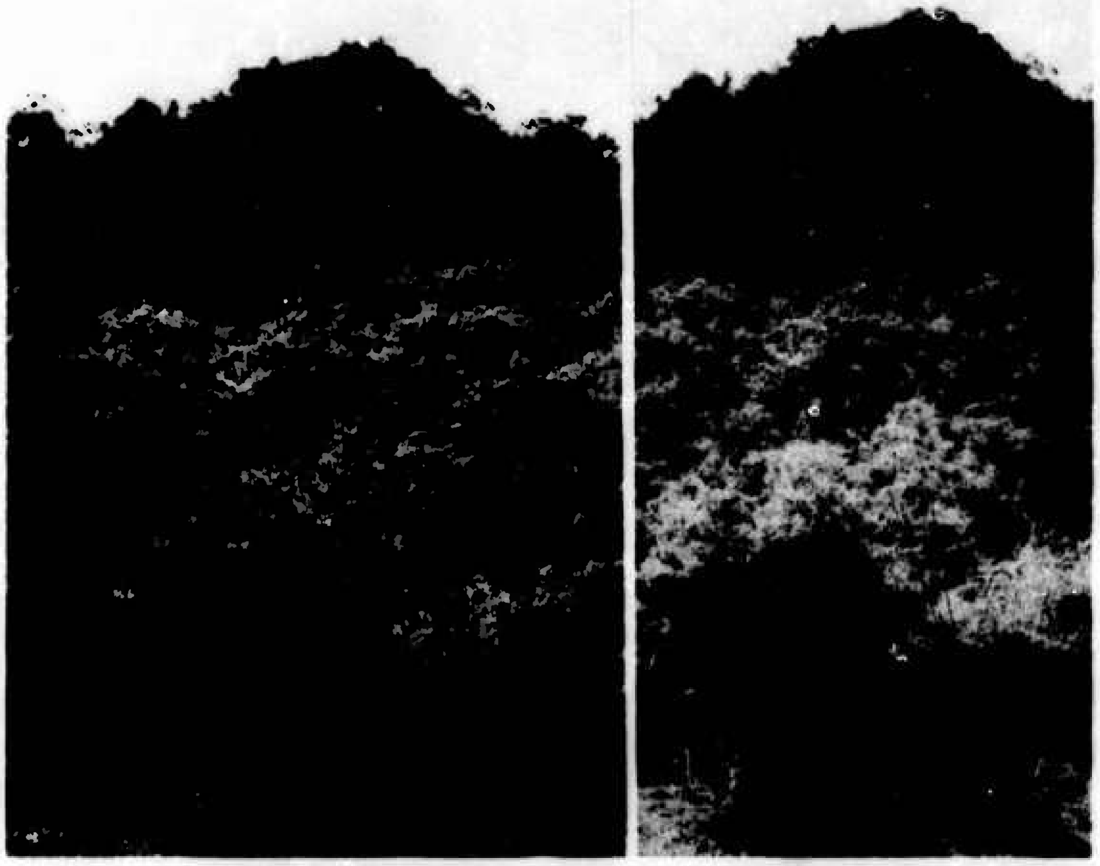


Fig. 165. Bamboo forest--bamboo clumps on lower slopes at site VG-55 (September 1964)

Fig. 166. Bamboo forest--thorny bamboo near edge of stand at site VG-60 (September 1964)

Fig. 167. Evergreen broadleaf forest in peninsular Thailand southwest of Hua Hin (December 1964)

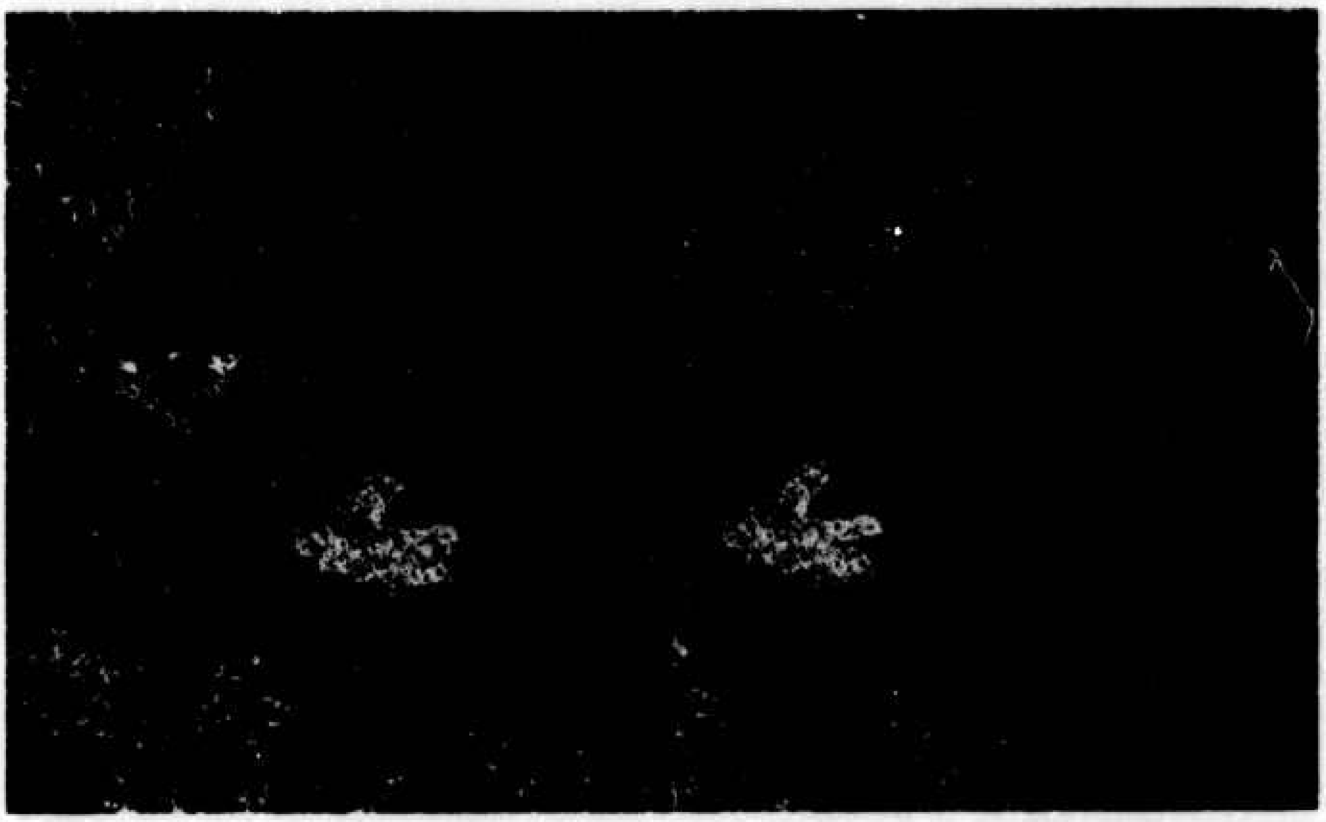


Fig. 168. Evergreen broadleaf forest north of the Mae Nam Pran Buri with partial clearings, stereopair (December 1964)

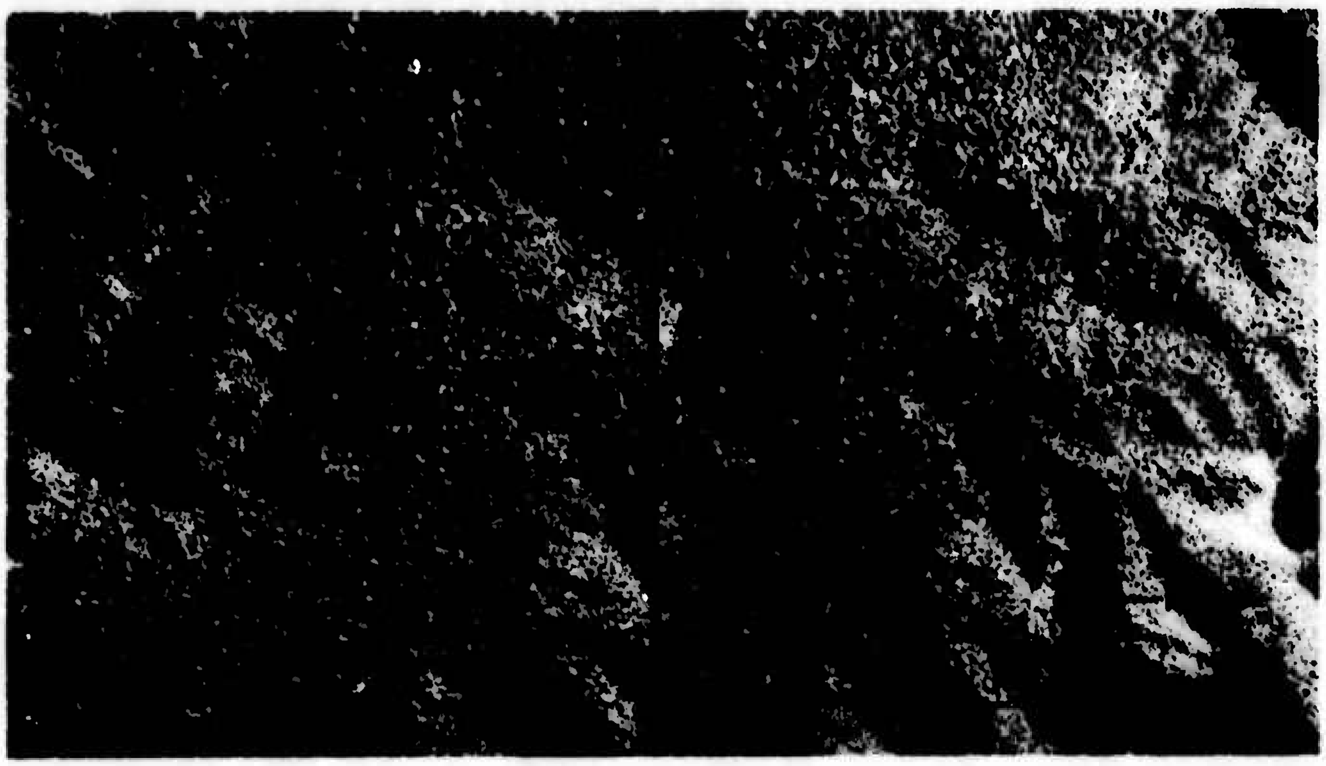


Fig. 169. Evergreen broadleaf forest 16 miles southwest of Hua Hin. Note the large emergent crowns above the surrounding canopy, stereopair (December 1964)

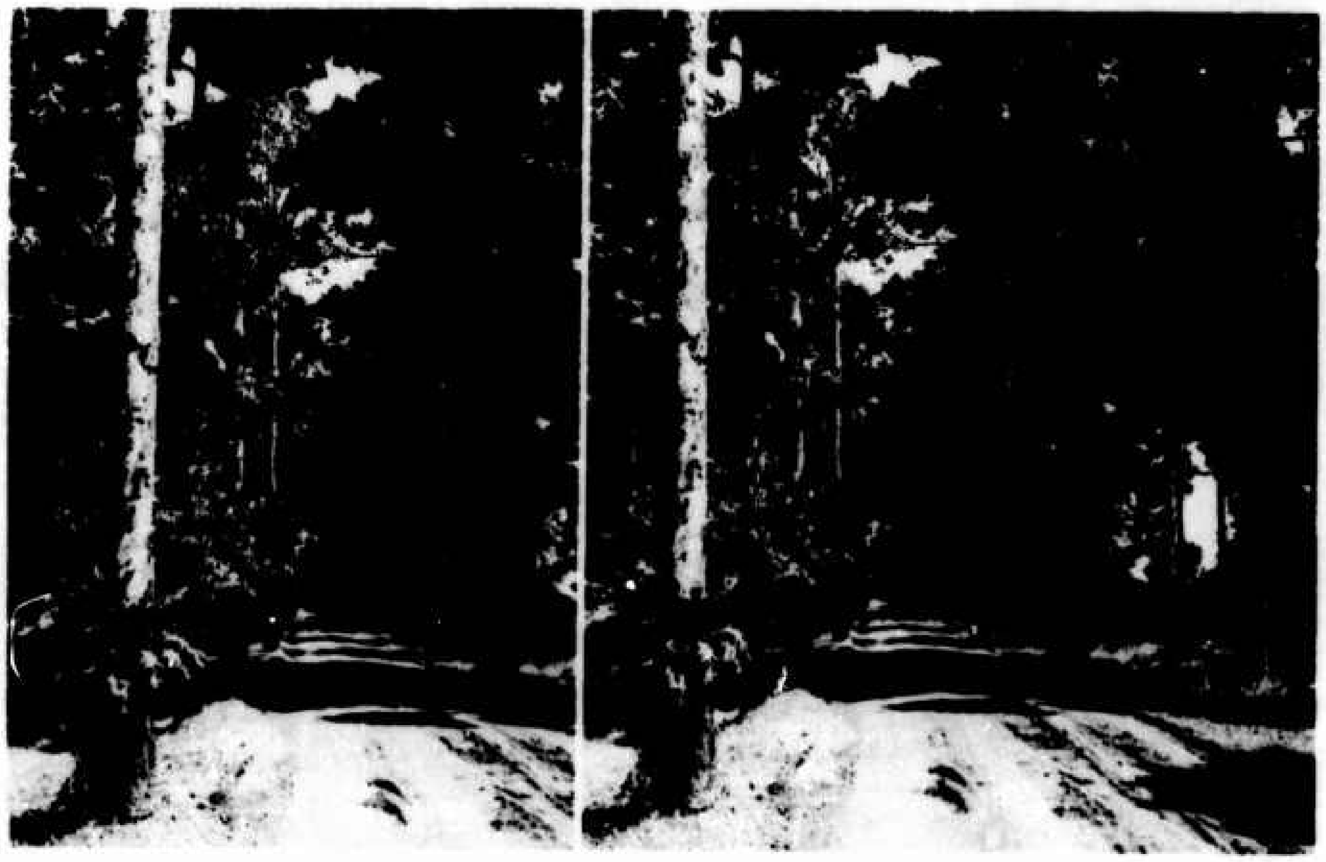


Fig. 170. Evergreen broadleaf forest--dipterocarp trees used for oil production, southeast of Chanthaburi (October 1964)

Fig. 171. Evergreen broadleaf forest--dense growth at site VG-99 southeast of Chanthaburi (October 1964)

Fig. 172. Evergreen broadleaf forest at site VG-99 southeast of Chanthaburi (October 1964)


Fig. 173. Mangrove swamp lining the Maenam Welu estuary south of Chanthaburi (December 1953)

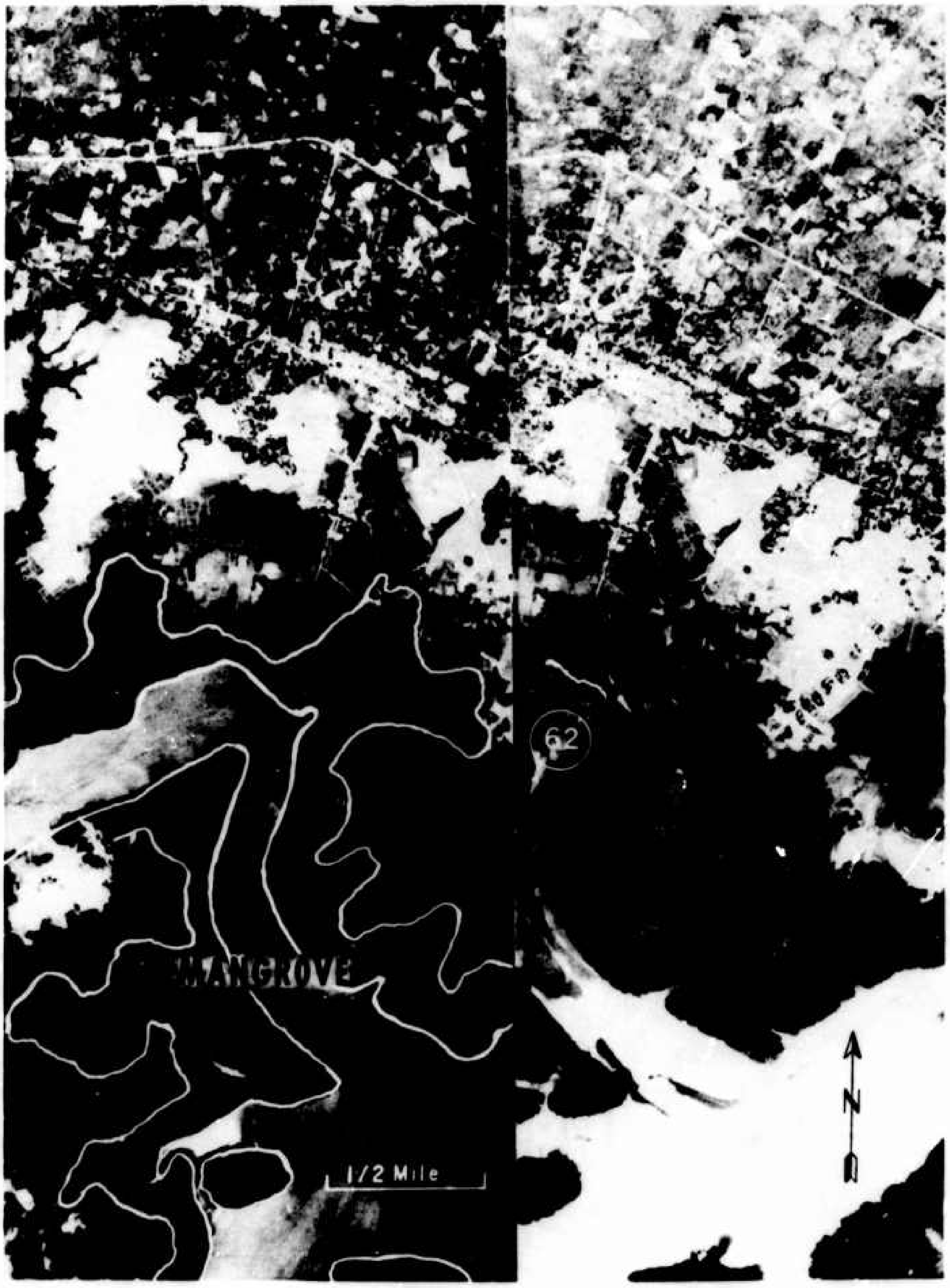



Fig. 174. Mangrove swamp in the Maenam Welu estuary. Site VG-62 is southwest of Amphoe Khlung, stereopair (December 1953)

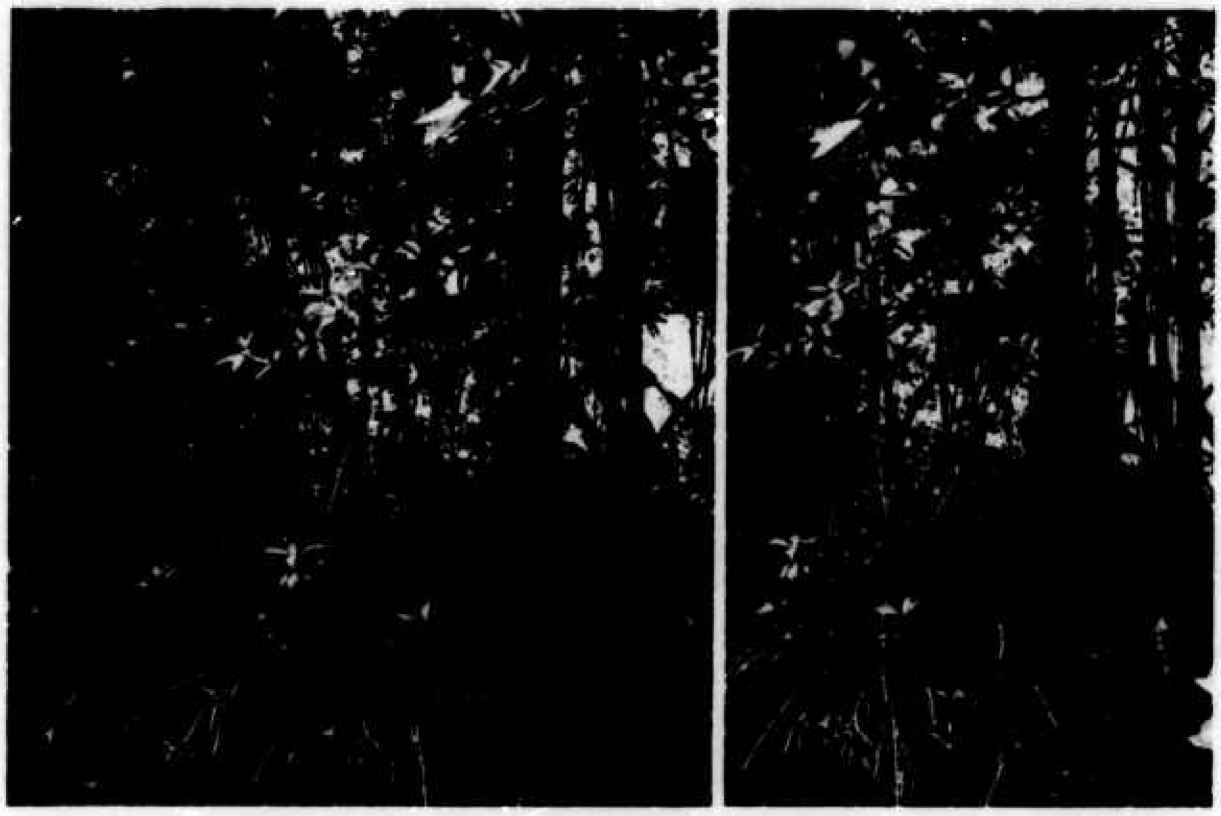


Fig. 175. Mangrove swamp--root system of mangrove tree exposed at low tide at site VG-62 (October 1964)

Fig. 176. Mangrove swamp--mangrove trees along narrow boat channel at site VG-62 (October 1964)

Fig. 177. Mangrove swamp--mangrove and nipa at high tide along the Khlong Song Phi Nong, Chanthaburi (October 1964)

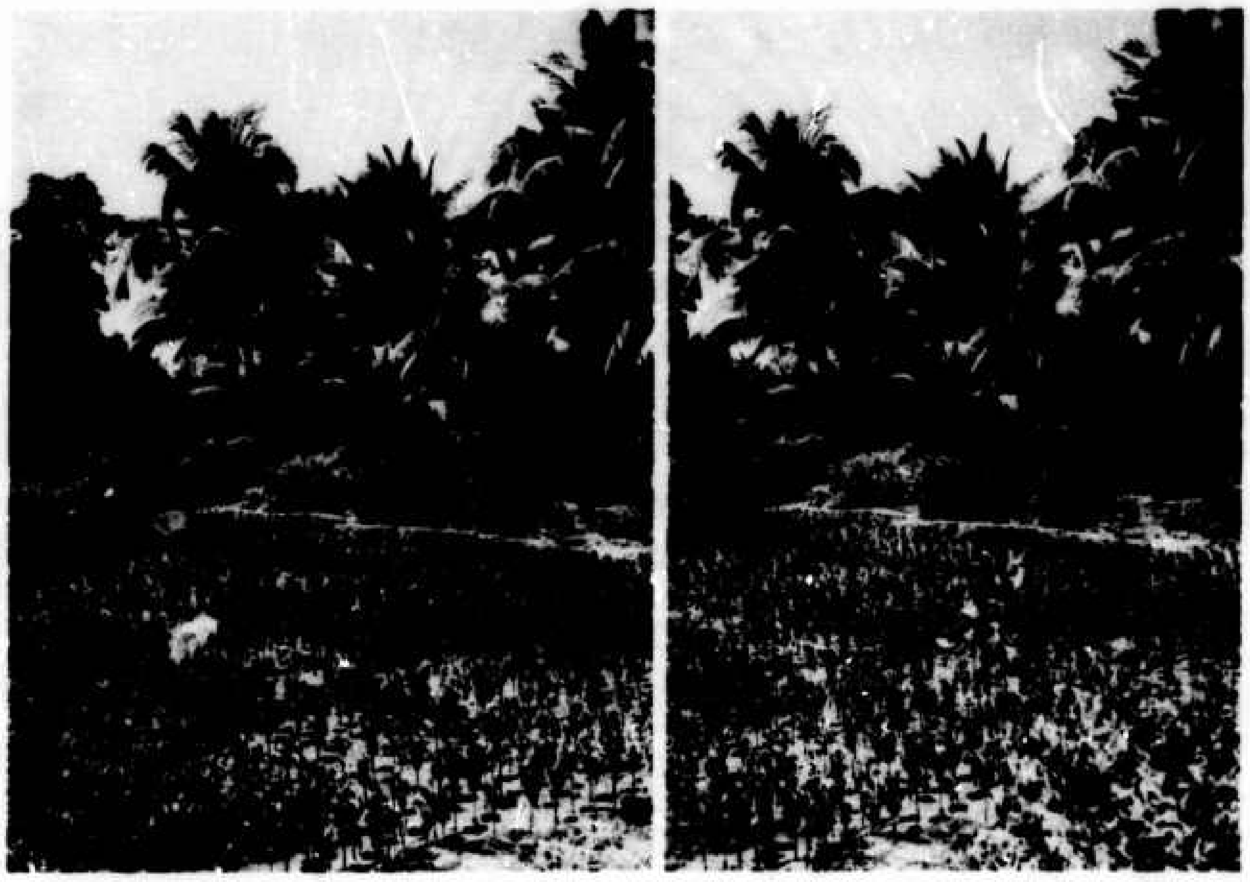


Fig. 178. Mangrove swamp--mangrove seedlings planted for charcoal production at site VG-83


Fig. 179. Nipa palm swamps adjacent to brackish channels and tidal areas of the Maenam Chanthaburi (February 1953)

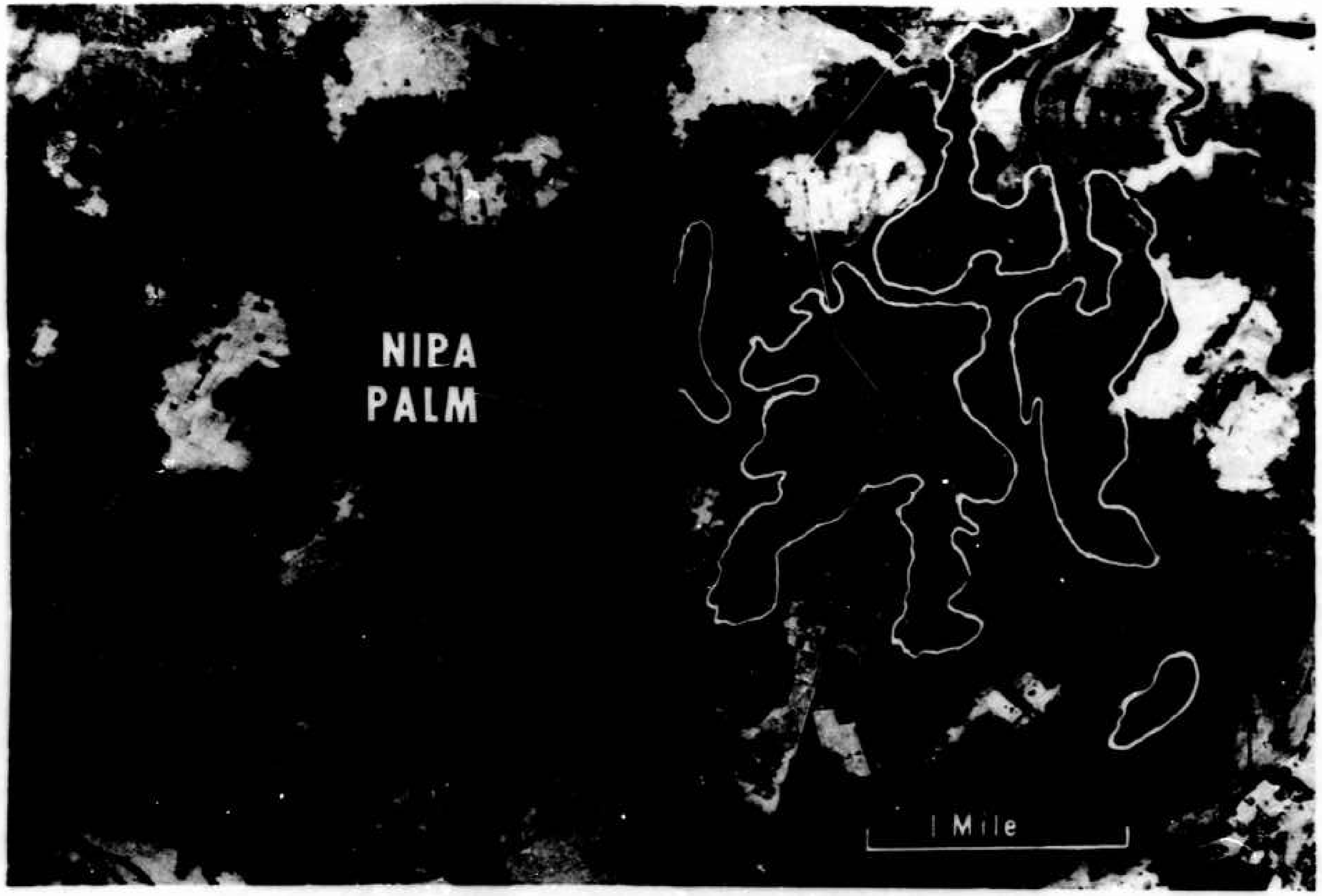



Fig. 180. Nipa palm swamp--stereopair of nipa palm area shown in fig. 179. Portions of this area have been cleared and drained for a coconut plantation (February 1953)

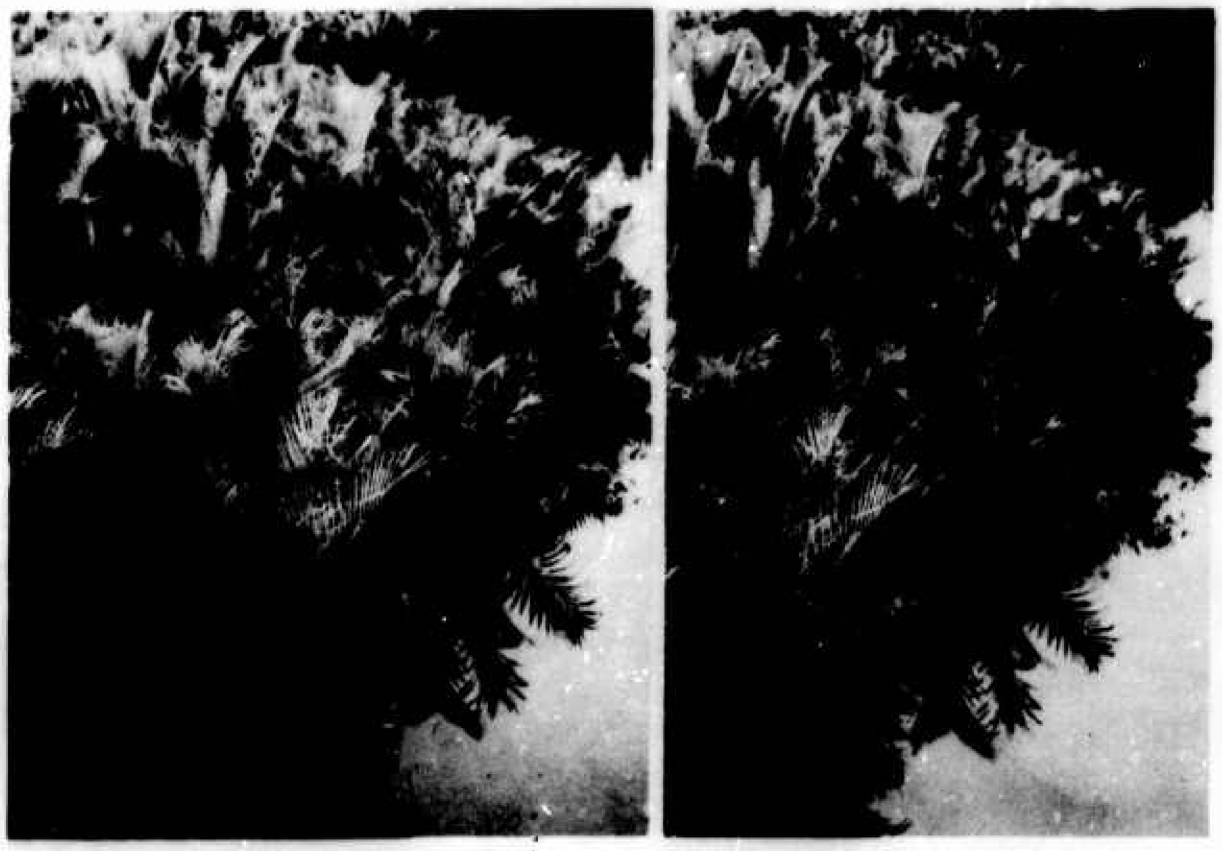


Fig. 181. Nipa palm along the brackish Khlong Nam Sai at site VG-70 (October 1964)

# HYDROLOGIC GEOMETRY

Table 5
Hydrologic Geometry
Summary of Data

| Site | Location: Map Sheet* | Location: Grid Coordinates | Date of Sample | Cross Sectional Profile, Fig. | Photo Illustrations, Fig.: Air Photo | Photo Illustrations, Fig.: Ground Photo |
|---|---|---|---|---|---|---|
| | | | **Coastal Features** | | | |
| HG-6-[illegible] | 5448IV | 847848 | 10-6-64 | -- | 183 | 186 |
| HG-15-4 | 5448III | 849815 | 10-15-64 | -- | 183 | 188 |
| HG-15-7 | 5448III | 818819 | 10-15-64 | -- | 183 | 191 |
| HG-15-[illegible] | 5448III | 883740 | 10-15-64 | 193 | -- | 192 |
| | | | **Meander Scars and Oxbow Lakes** | | | |
| HG-22-5 | 5154I | 044077 | 9-22-64 | -- | -- | 202, 203 |
| HG-22-6 | 5154I | 969097 | 9-22-64 | -- | -- | 200, 201 |
| 2-H-22-5 | 5154I | 044077 | 1-19-65 | 204 | -- | -- |
| 2-H-22-6 | 5154I | [illegible]097 | 1-19-65 | 204 | -- | -- |
| | | | **Large Canals** | | | |
| HG-21-4 | 5153I | 973789 | 9-21-64 | 209 | -- | 208 |
| 2-H-14-[illegible] | 5154II | [illegible] | 1-22-65 | 209 | -- | -- |
| 2-H-15-7 | 5153I | 044805 | 2-6-65 | 209 | -- | -- |
| | | | **Small Canals and Irrigation Ditches** | | | |
| 2-H-14-6 | 5154II | 903953 | 1-21-65 | 218 | 210 | 212, 213 |
| 2-H-14-10 | 5154III | 882967 | 1-22-65 | 219 | 210 | 216, 217 |
| 2-H-14-11 | 5154II | [illegible]1961 | 1-21-65 | 219 | 210 | 214, 215 |
| 3-H-28 | 4867III | 055814 | 9-10-64 | 220 | -- | -- |
| 3-H-3[illegible] | 4867IV | 079831 | 9-10-64 | 220 | -- | -- |
| 3-H-123 | 4867IV | 048842 | 11-1-64 | 220 | -- | -- |
| | | | **Small Streams** | | | |
| 3-H-29 (6)** | 4867III | 058815 | 9-10-64 | 229 | 226 | -- |
| 3-H-30 (5) | 4867III | 062820 | 9-10-64 | 229 | 226 | -- |
| 3-H-31 (7) | 4867IV | 077828 | 9-22-64 | 230 | 226 | -- |
| 3-H-33 (8) | 4867IV | 083834 | 9-11-64 | 230 | 226 | -- |
| 3-H-37 (4) | 4867IV | 048828 | 9-13-64 | 229 | 226 | -- |
| 3-H-39 (3) | 4867IV | 062851 | 9-14-64 | 228 | 226 | -- |
| 3-H-40 (1) | 4867IV | [illegible] | 9-14-64 | 228 | 226 | -- |
| 3-H-122 (2) | 4867IV | 046826 | 11-1-64 | 228 | 226 | -- |
| | | | **Borrow Pits** | | | |
| HG-14-1 | 5154II | [illegible] | 9-14-64 | -- | -- | 236 |
| HG-14-3 | 5154II | [illegible] | 9-14-64 | 238 | -- | 235 |
| 1-H-27 | 4958II | 033456 | 8-23-64 | 238 | 231 | -- |
| 1-H-32 | 4958II | 023474 | 8-25-64 | 238 | 231 | -- |
| | | | **Mountain Streams** | | | |
| HG-9-5 | 5349II | 232077 | 10-9-64 | -- | -- | 252 |
| HG-11-3 (1)† | 5448IV | 917864 | 10-11-64 | -- | 243 | 245 |
| HG-11-5 (2) | 5448IV | 936863 | 10-11-64 | 253 | 243 | 246 |
| HG-15-8 (3) | 5448IV | 928842 | 10-15-64 | 253 | 243 | 247 |
| HG-17-4 (4) | 5448III | 933823 | 10-17-64 | 253 | 243 | 248 |
| HG-17-5 (5) | 5448III | 936817 | 10-17-64 | 253 | 243 | 249 |
| HG-17-8 (7) | 5448III | 966794 | 10-17-64 | 253 | 243 | 251 |
| HG-17-9 (6) | 5448III | 956790 | 10-17-64 | 253 | 243 | 250 |

* Army Map Service, L708, 1:50,000.
** Numbers in parentheses are identification numbers used in fig. 226.
† Numbers in parentheses are identification numbers used in fig. 243.

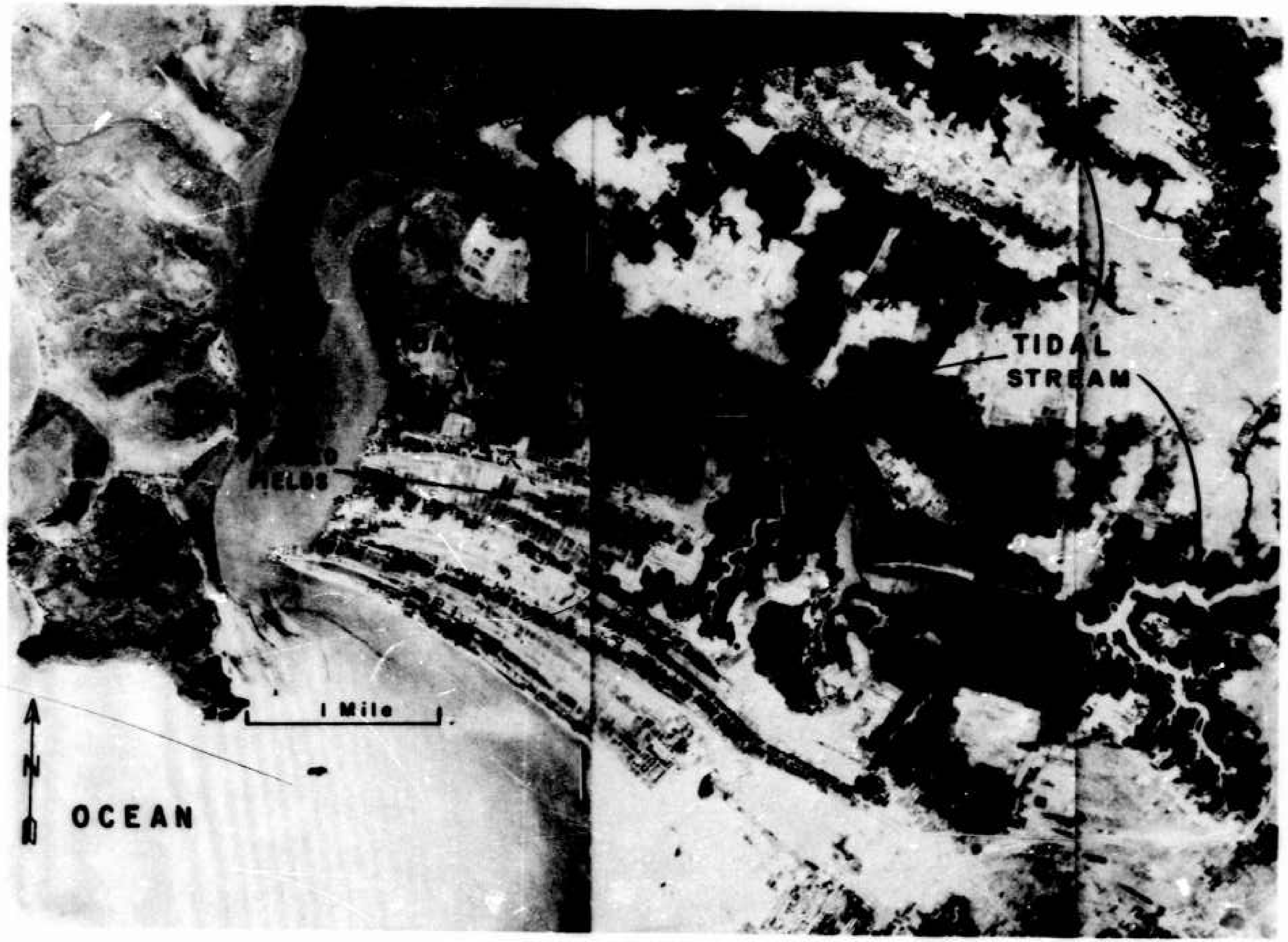



Fig. 182. Coastal features, Chanthaburi (February 1953)

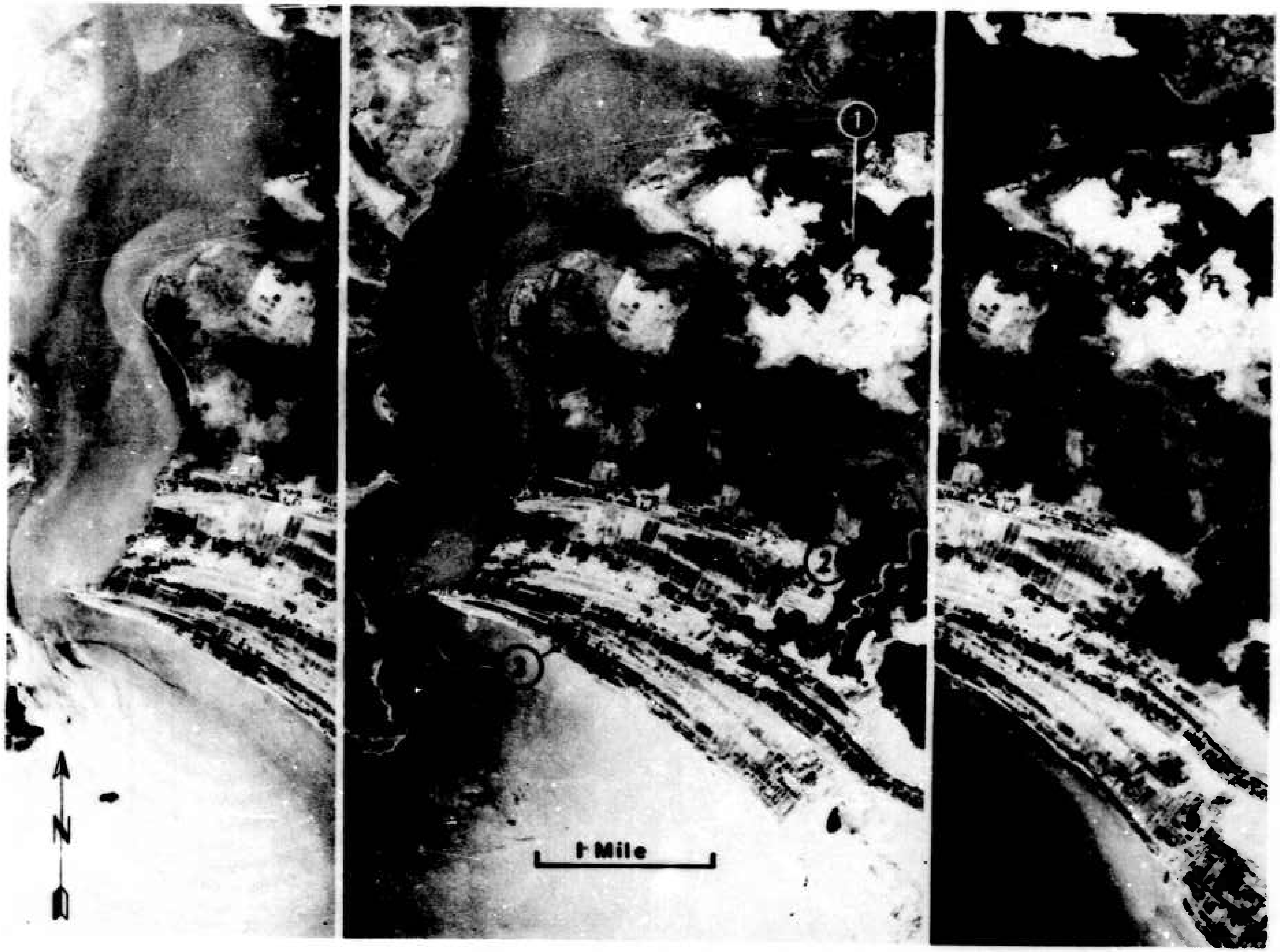



Fig. 183. Coastal features--stereotriplet of a portion of fig. 182 showing locations of sites (1) HG-6-9, (2) HG-15-4, and (3) HG-15-7 (February 1953)

Fig. 184. Coastal features--tidal stream patterns, Chanthaburi (October 1964)

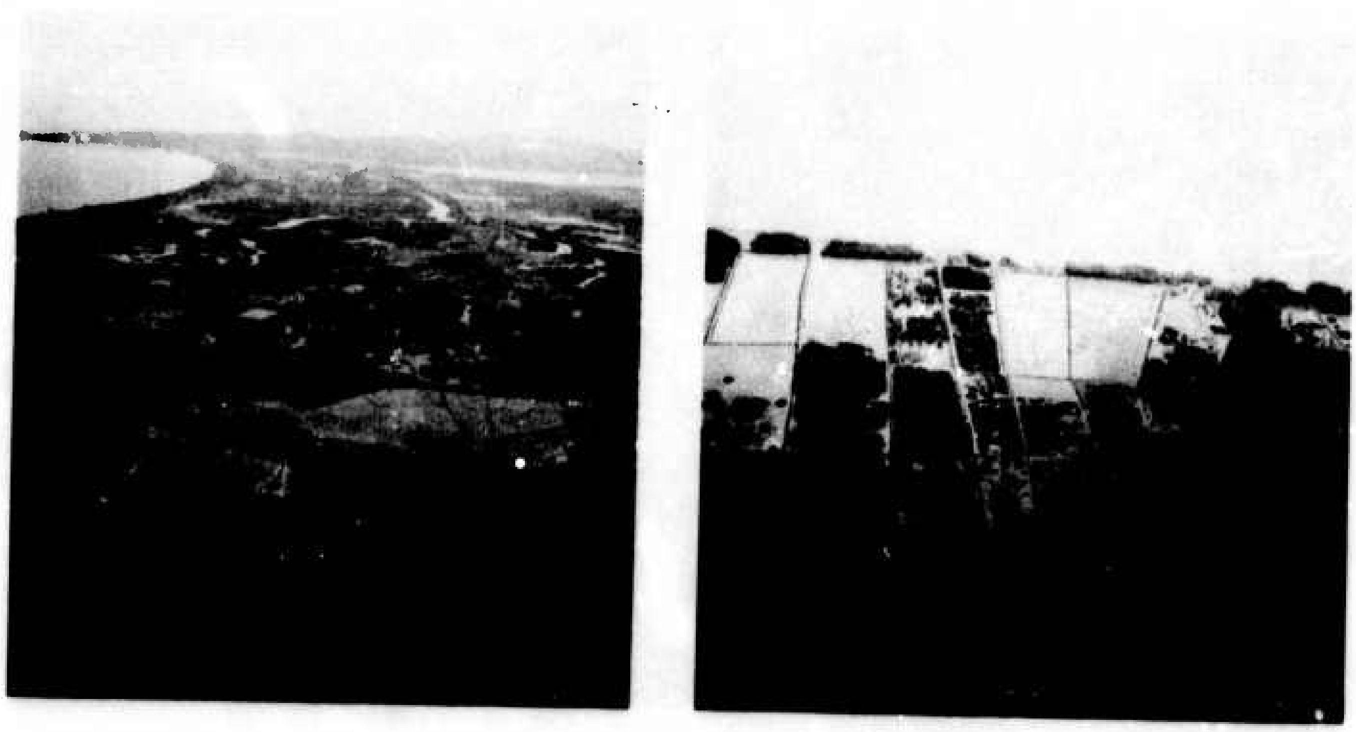


Fig. 185. Coastal features--flooded fields in vicinity of the Gulf of Siam south of Chanthaburi (October 1964)

Fig. 186. Coastal features--flooded banks of tidal stream (site HG-6-9) at location 1 in fig. 183 (October 1964)

Fig. 187. Coastal features--headwater area of tidal stream (October 1964)

Fig. 188. Coastal feature--tidal stream (site HG-15-4) at location 2 in fig. 183, looking upstream (October 1964)

Fig. 189. Coastal features--fish trap arrangement in an estuary (October 1964)

Fig. 190. Coastal features--water-level view of fish trap shown in fig. 189 (October 1964)

Fig. 191. Coastal features--water-filled swale between beach ridges (site HG-15-7) at location 3 in fig. 183 (October 1964)

Fig. 192. Coastal features--shrimp ponds along the coast at site HG-19-2 in the Chanthaburi area. A cross section appears in fig. 193 (October 1964)

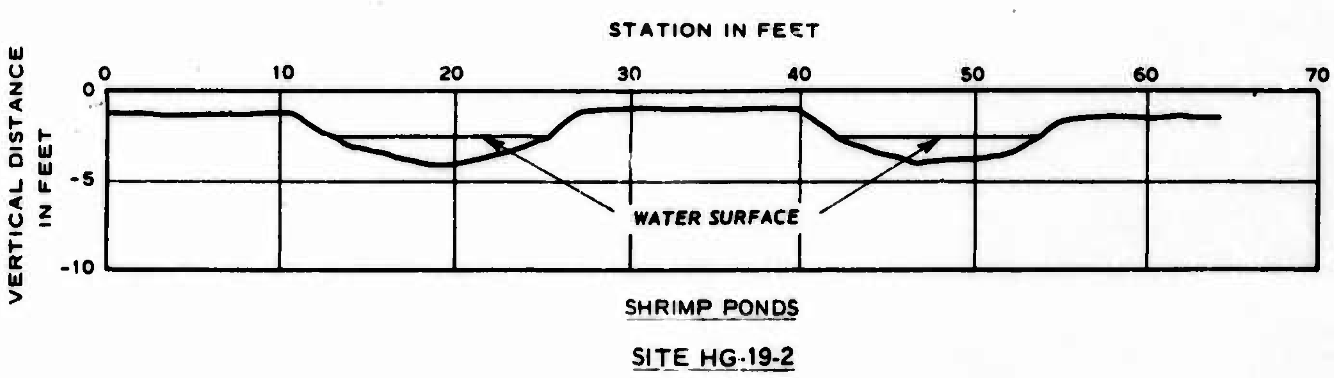



Fig. 193. Coastal features--cross section of shrimp ponds shown in fig. 192 (19 October 1964)

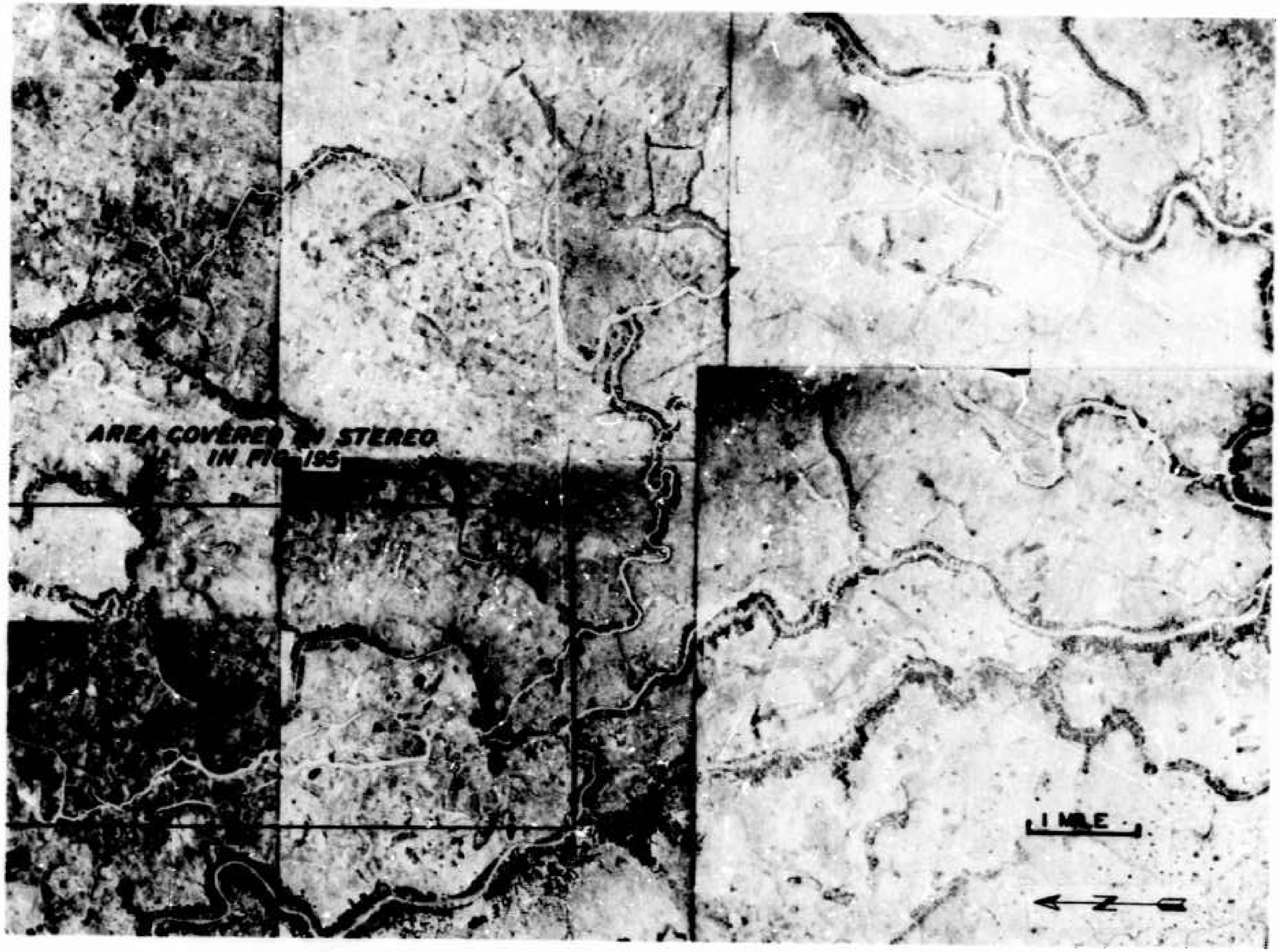



Fig. 194. Distributary stream system north of Ayutthaya in the Lop Buri area (January 1953)

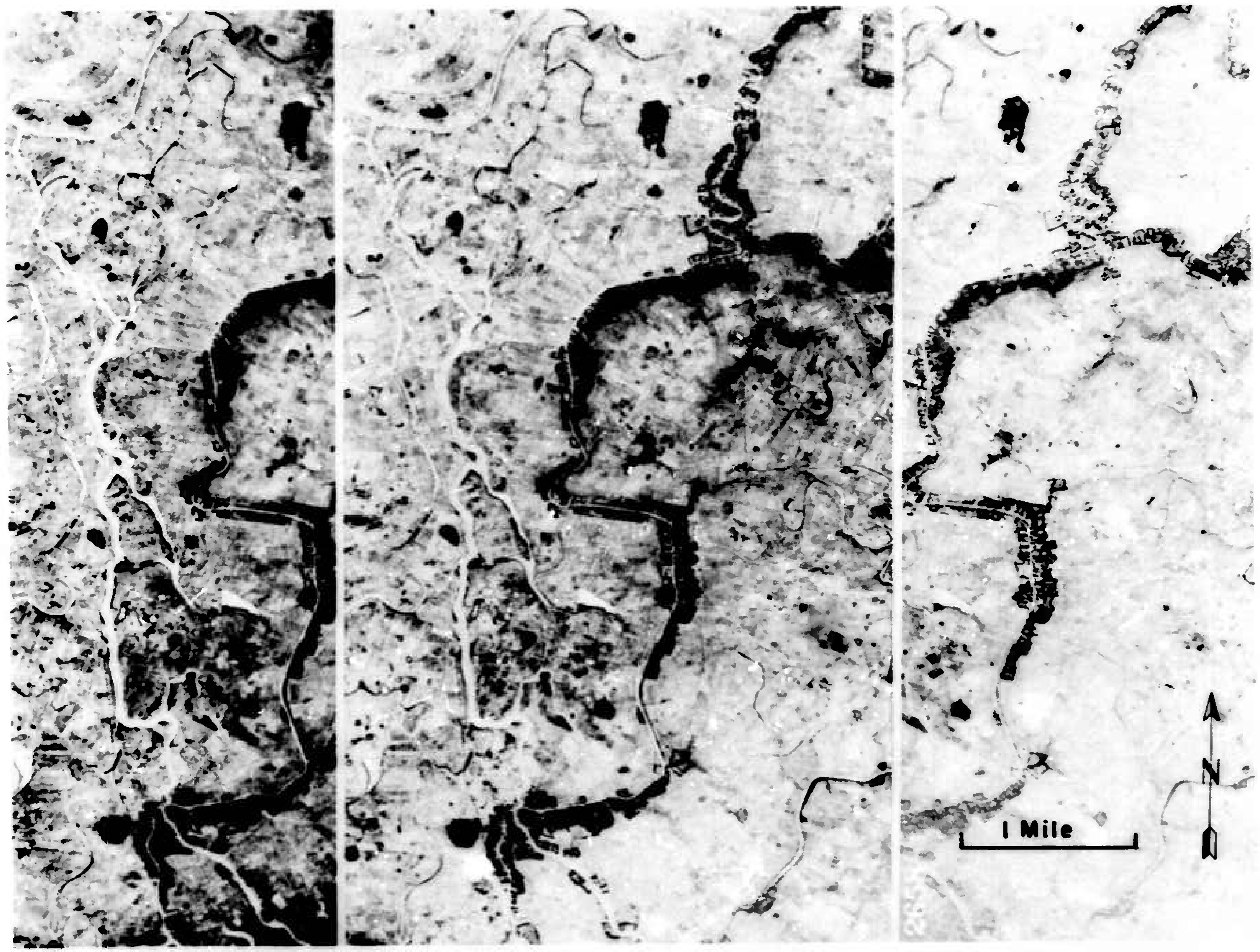



Fig. 195. Distributary streams--stereotriplet of the distributary stream system shown in fig. 194 (January 1953)

Fig. 196. Distributary stream pattern in the Lop Buri area during a period of flooding (October 1964)

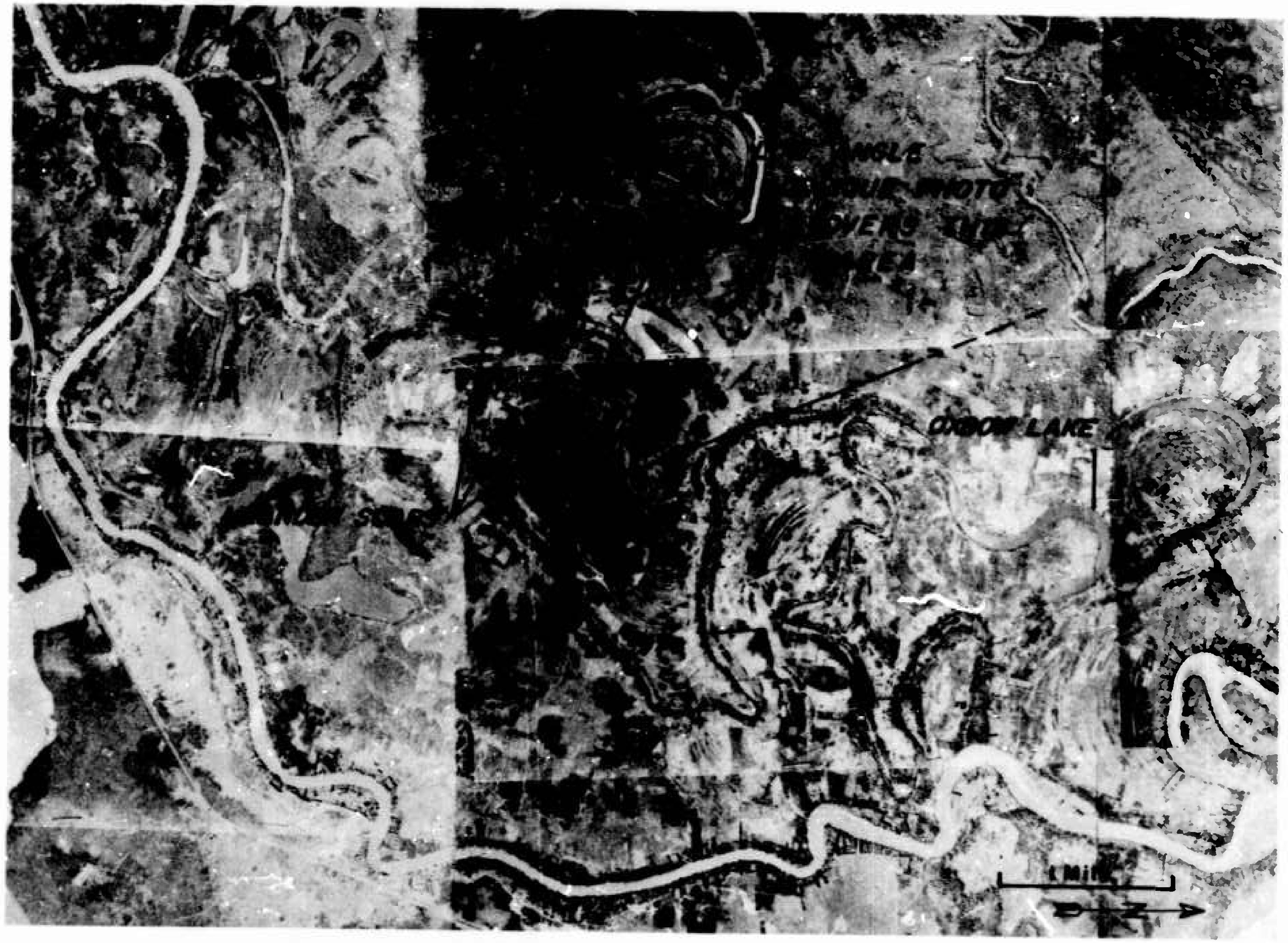



Fig. 197. Meander scar and oxbow lake pattern in Nakhon Sawan (January 1955)

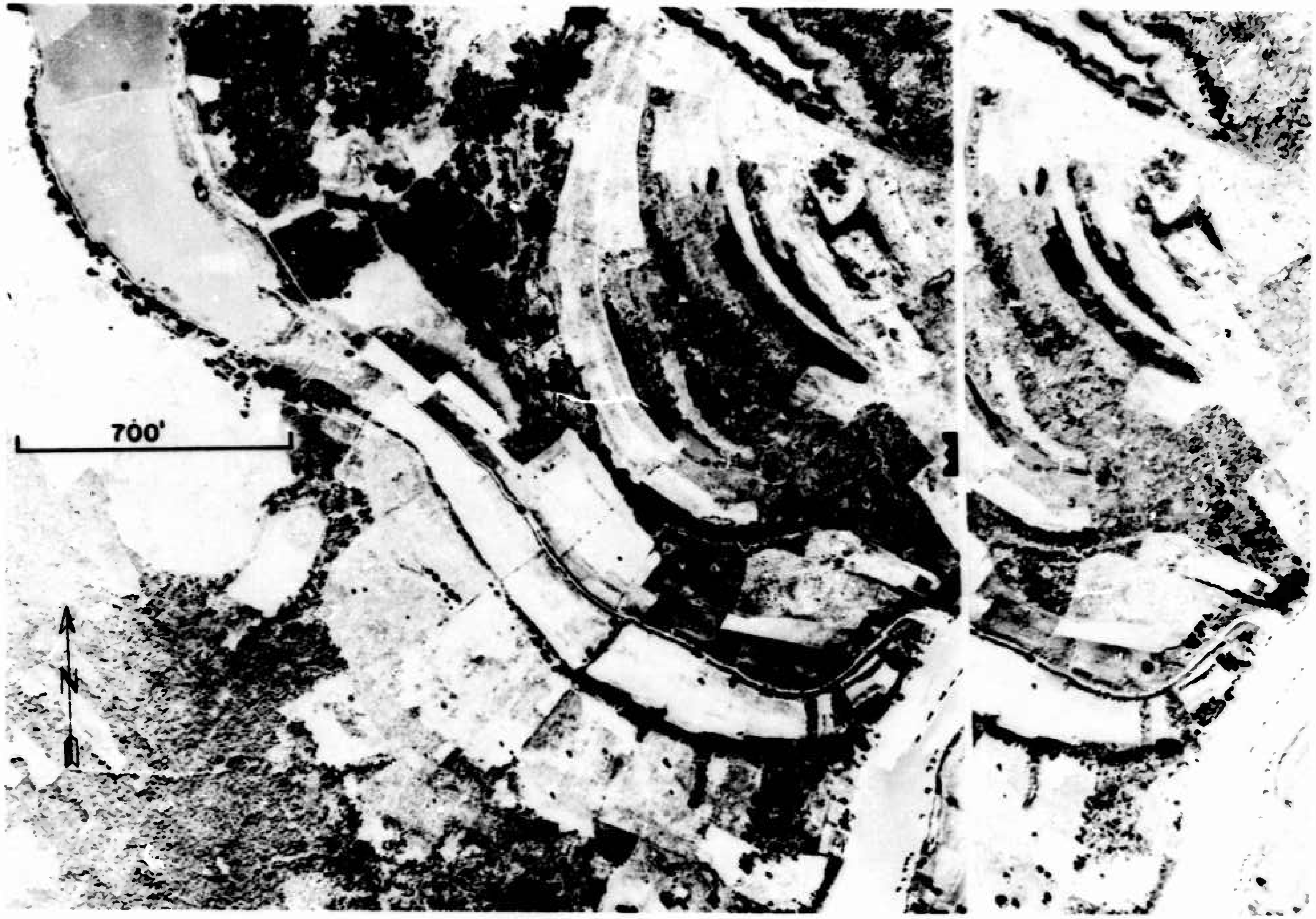



Fig. 198. Meander scars and oxbow lakes--stereopair showing meander scars in Nakhon Sawan area (January 1965)


Fig. 199. Meander scars and oxbow lakes--oblique aerial photograph showing flooded meander scars and oxbow lake which appear in fig. 197 (September 1964)

Fig. 200. Meander scars and oxbow lakes--view south over oxbow lake in Lop Buri area, site HG-22-6 (September 1964)

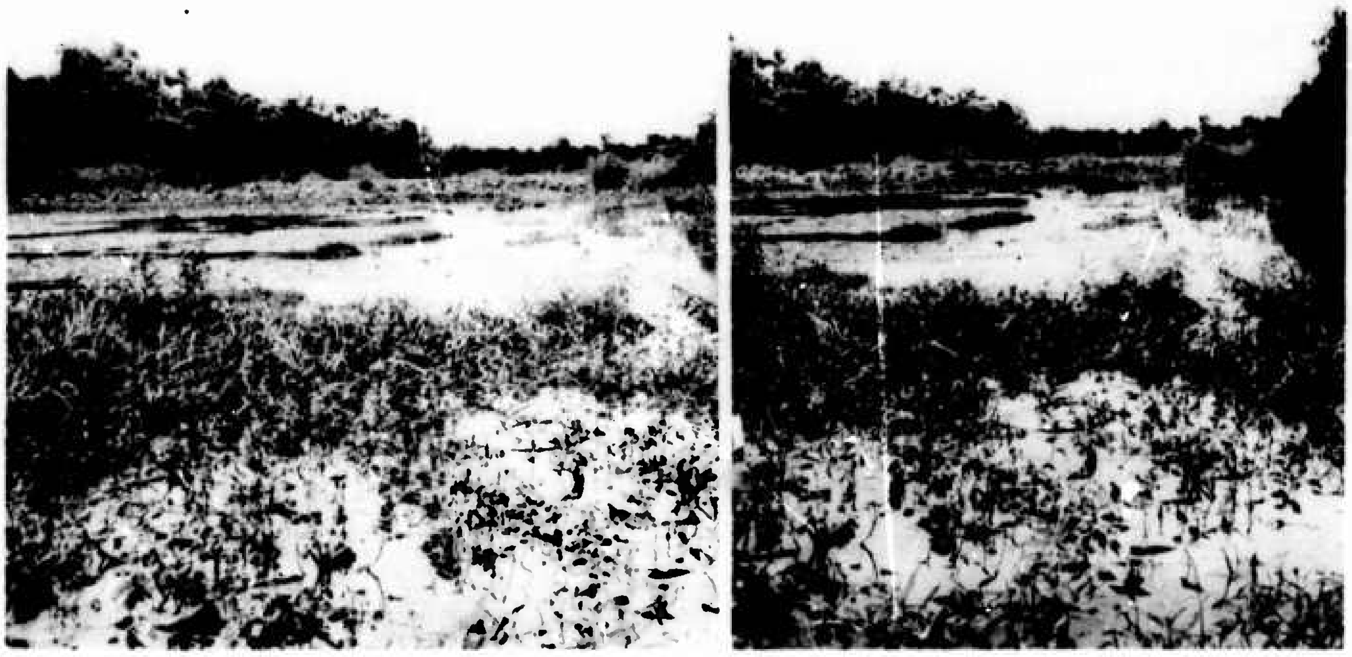
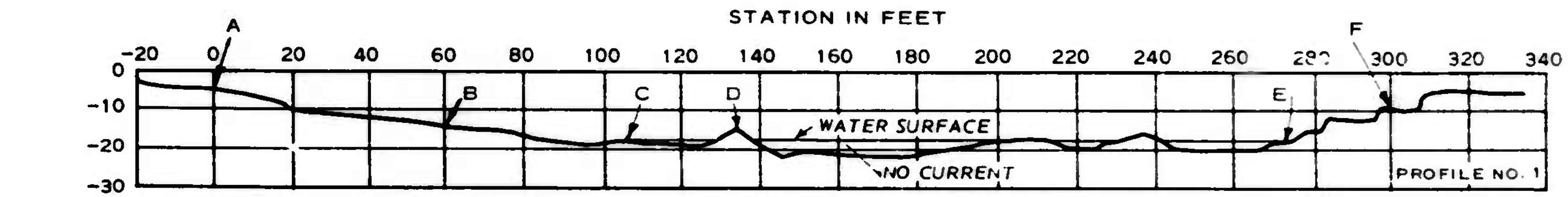


Fig. 201. Meander scars and oxbow lakes--view north over oxbow lake in Lop Buri area, site HG-22-6 (September 1964)

Fig. 202. Meander scars and oxbow lakes--view east over vegetation-filled oxbow lake in Lop Buri area, site HG-22-5 (September 1964)

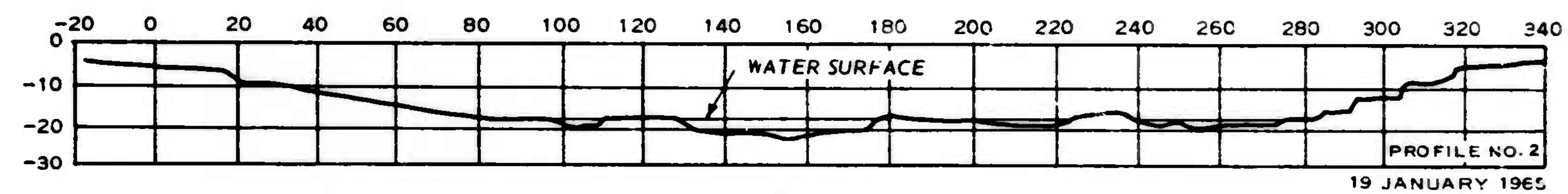
Fig. 203. Meander scars and oxbow lakes--view west over vegetation-filled oxbow lake in Lop Buri area, site HG-22-5 (September 1964)



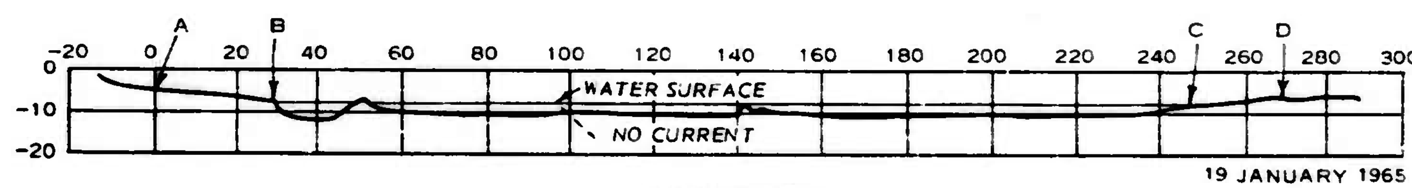

AVERAGE CONE INDEX

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 0-6" | 300+ | 172 | 16 | 161 | 8 | 300+ |
| 6-12" | -- | 272 | 67 | 147 | 28 | -- |

CLAYEY SAND BOTTOM




BUNG
SITE 2-H-22-5




NONG NGONG
SITE 2-H-22-6

AVERAGE CONE INDEX

| | A | B | C | D |
|---|---|---|---|---|
| 0-6" | 300+ | 18 | 20 | 266 |
| 6-12" | -- | 42 | 52 | 300+ |

CLAY BOTTOM

Fig. 204. Meander scars and oxbow lakes--cross sections of oxbow lakes in the Lop Buri area

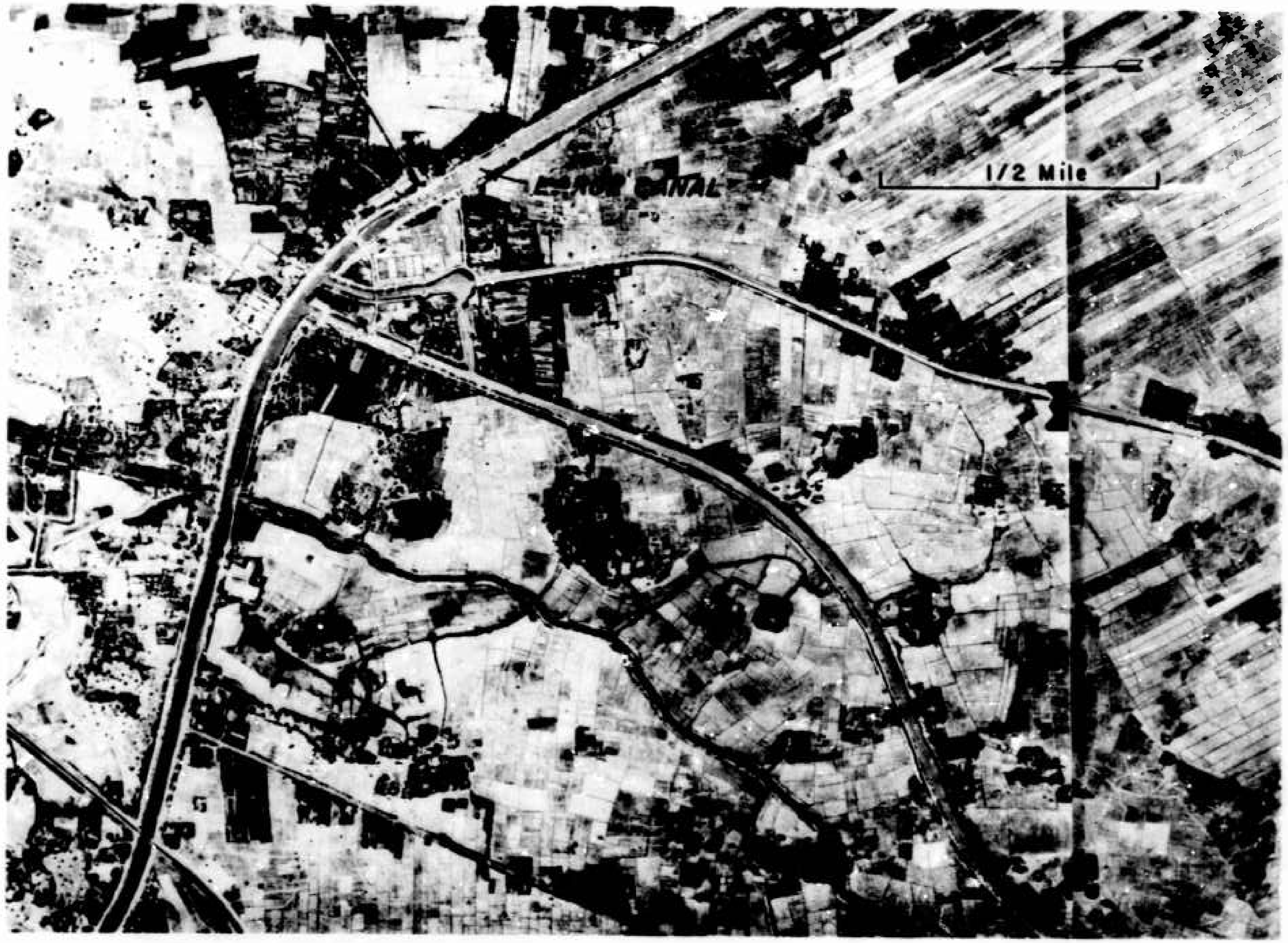



Fig. 205. Large canal complex south of Sara Buri (December 1964)

Fig. 206. Large canal complex presented in fig. 205, stereotriplet (December 1964)

Fig. 207. Large canal in the Lop Buri area
(October 1964)

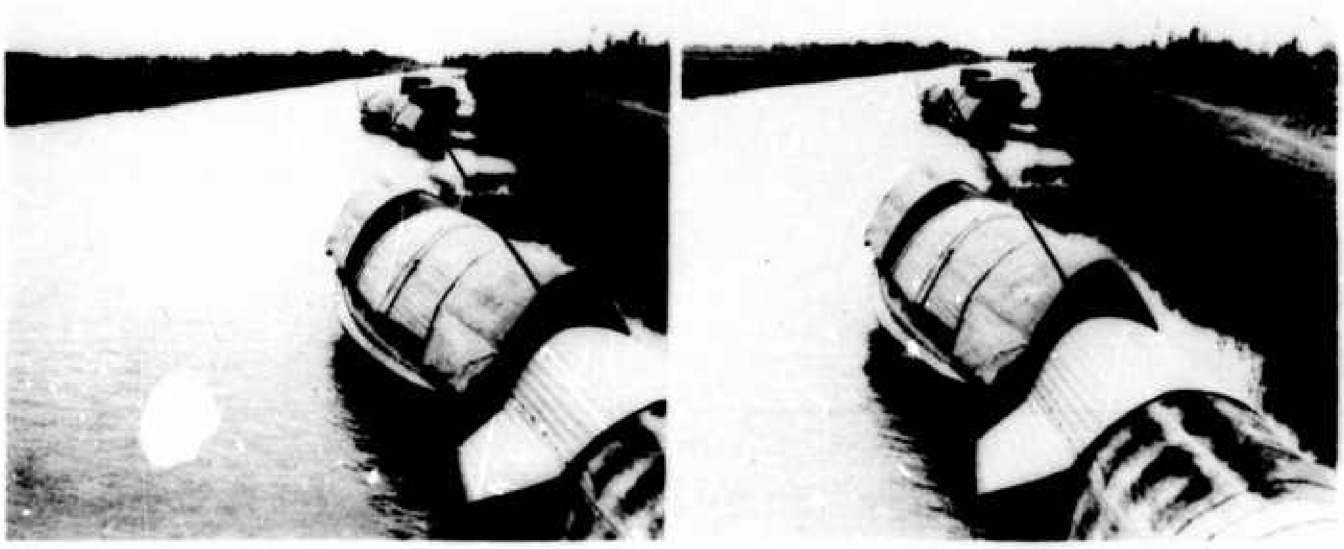
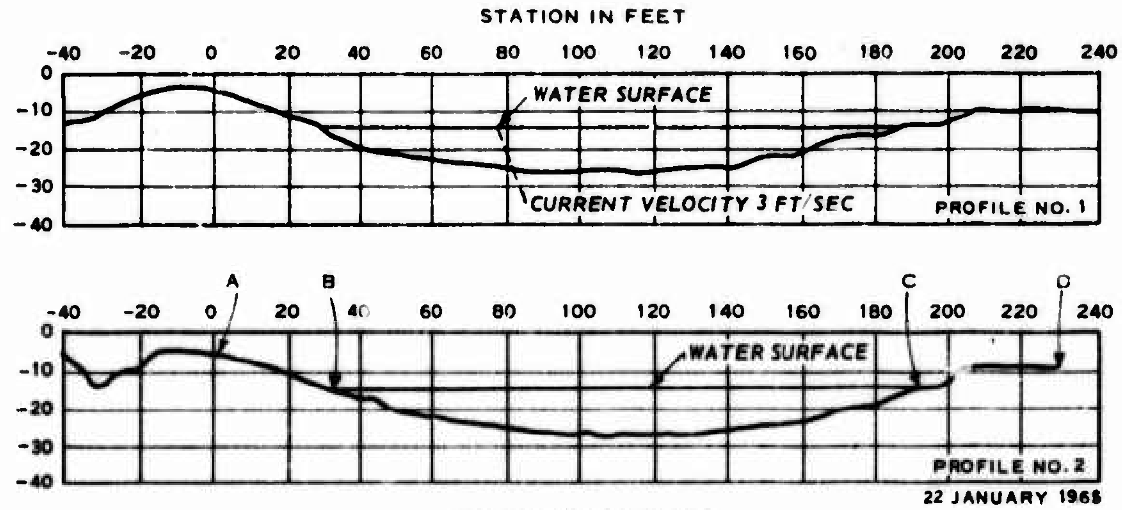


Fig. 208. Large canal at site HG-21-4 in the Lop Buri area
(September 1964)

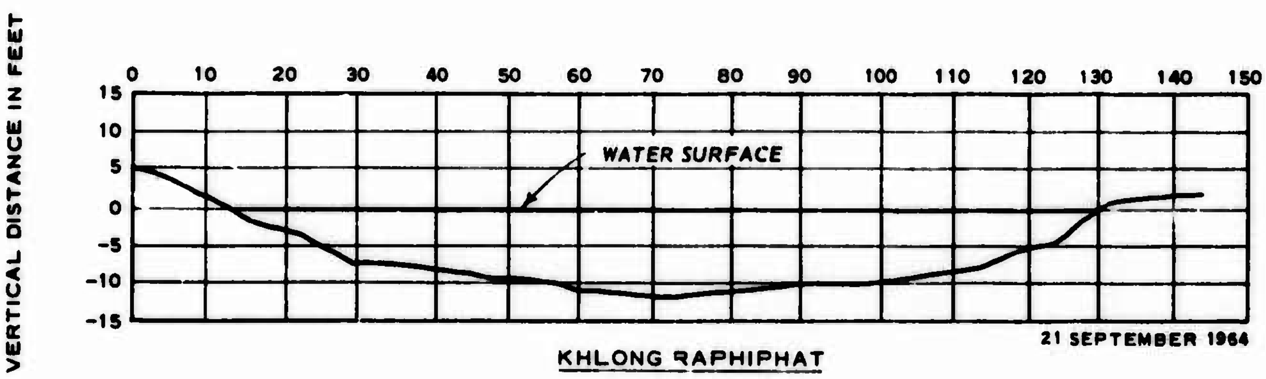



KHLONG RAPHIPHAT

SITE 2-H-14-4

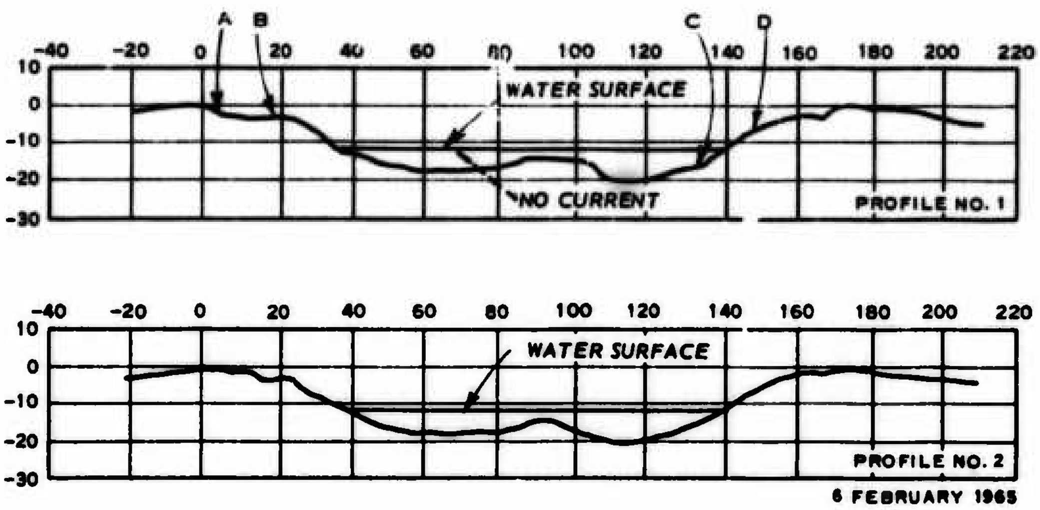
AVERAGE CONE INDEX

| | A | B | C | D | |
|---|---|---|---|---|---|
| 0-6" | 300+ | 33 | 40 | 300+ | CLAY BOTTOM |
| 6-12" | -- | 47 | 86 | -- | |




KHLONG RAPHIPHAT

SITE HG-21-4




KHLONG SIP SAM

SITE 2-H-15-7

AVERAGE CONE INDEX

| | A | B | C | D | |
|---|---|---|---|---|---|
| 0-6" | 300+ | 62 | 74 | 300+ | CLAY BOTTOM |
| 6-12" | -- | 144 | 99 | -- | |

Fig. 209. Large canals--cross sections of large canals in the Lop Buri area


210. Small canals and irrigation ditches--system of small canals in Lop Buri showing location of sites (1) 2-H-14-6, (2) 2-H-14-11, and (3) 2-H-14-10 (December 1964)

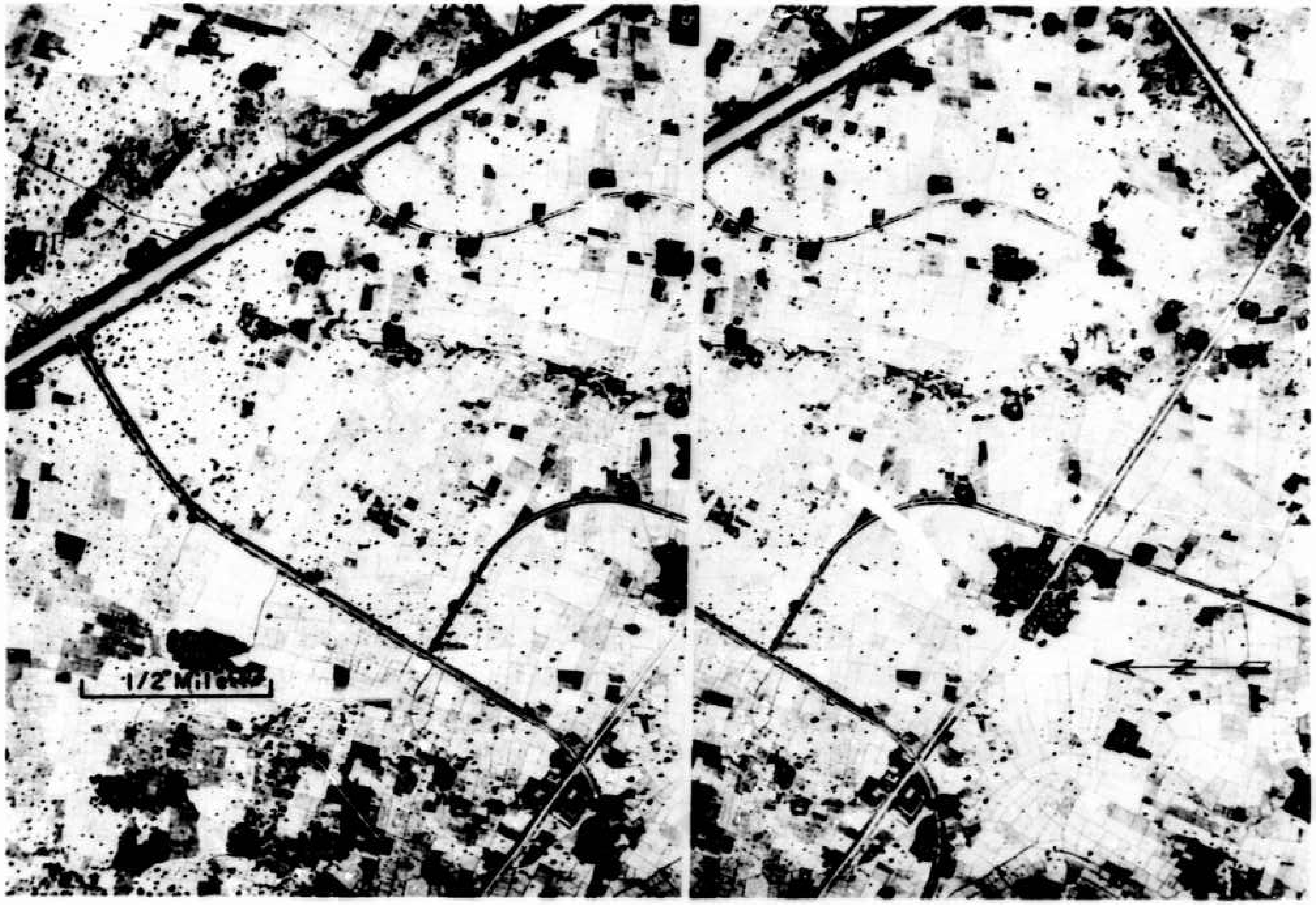



Fig. 211. Small canals and irrigation ditches--stereopair of a portion of the area covered in fig. 210 (December 1964)

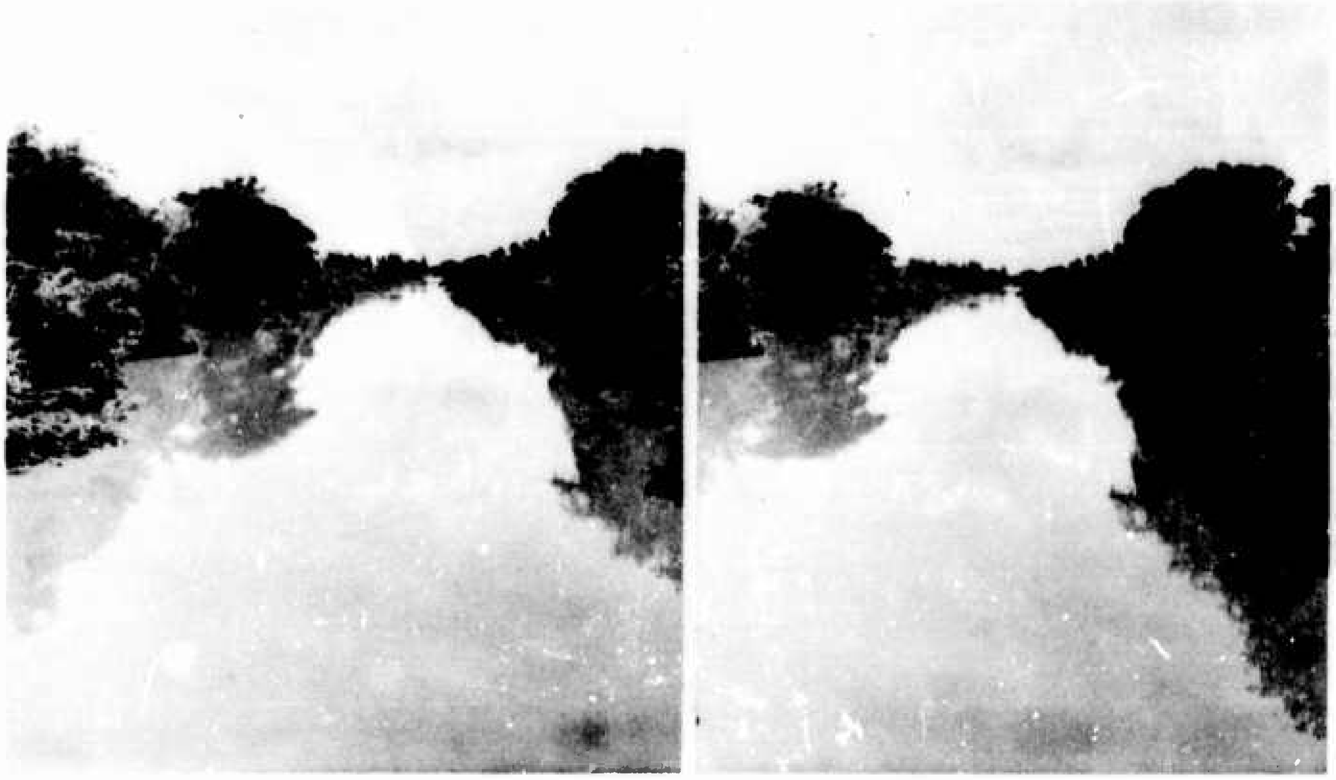


Fig. 212. Small canals and irrigation ditches--site 2-H-14-6 at location 1 in fig. 210, view to northeast (September 1964)

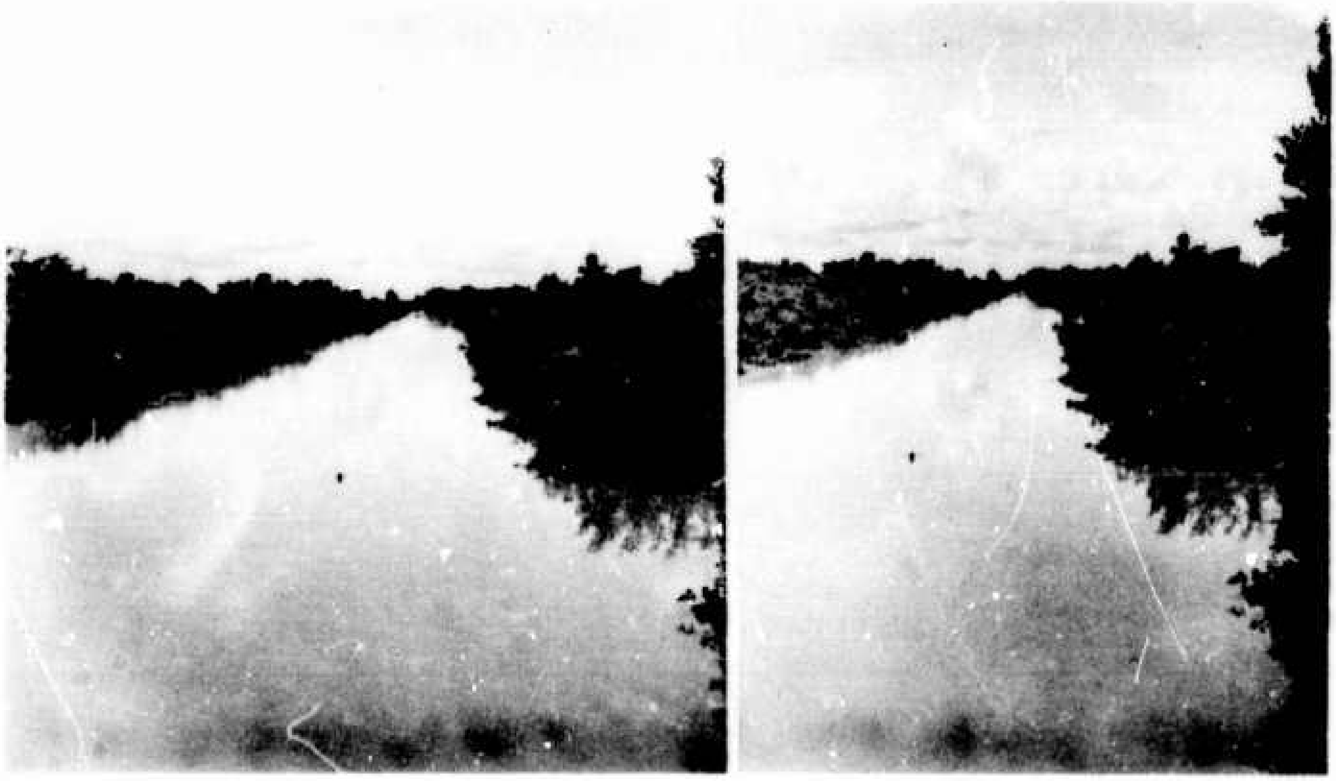


Fig. 213. Small canals and irrigation ditches--site 2-H-14-6 at location 1 in fig. 210, view to southwest (September 1964)

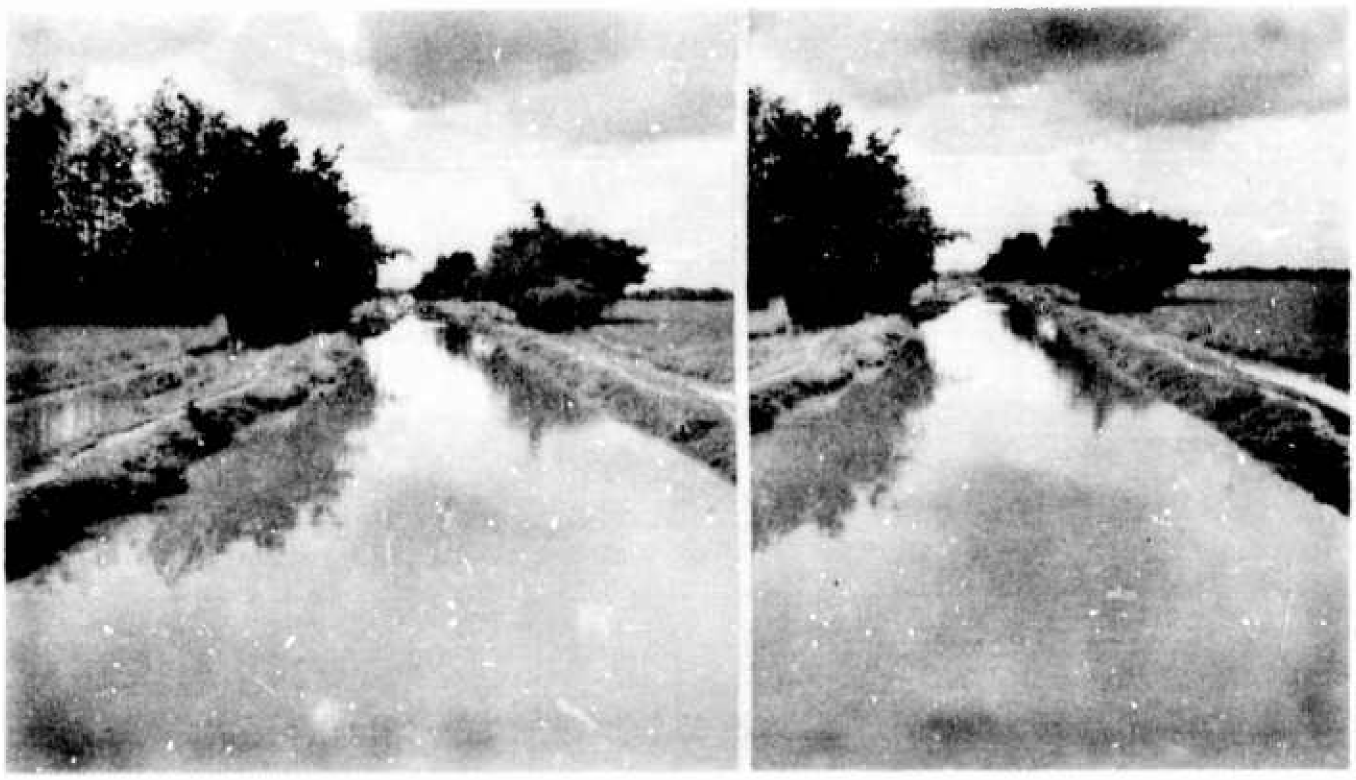


Fig. 214. Small canals and irrigation ditches--site 2-H-14-11 at location 2 in fig. 210, view northward (September 1964)

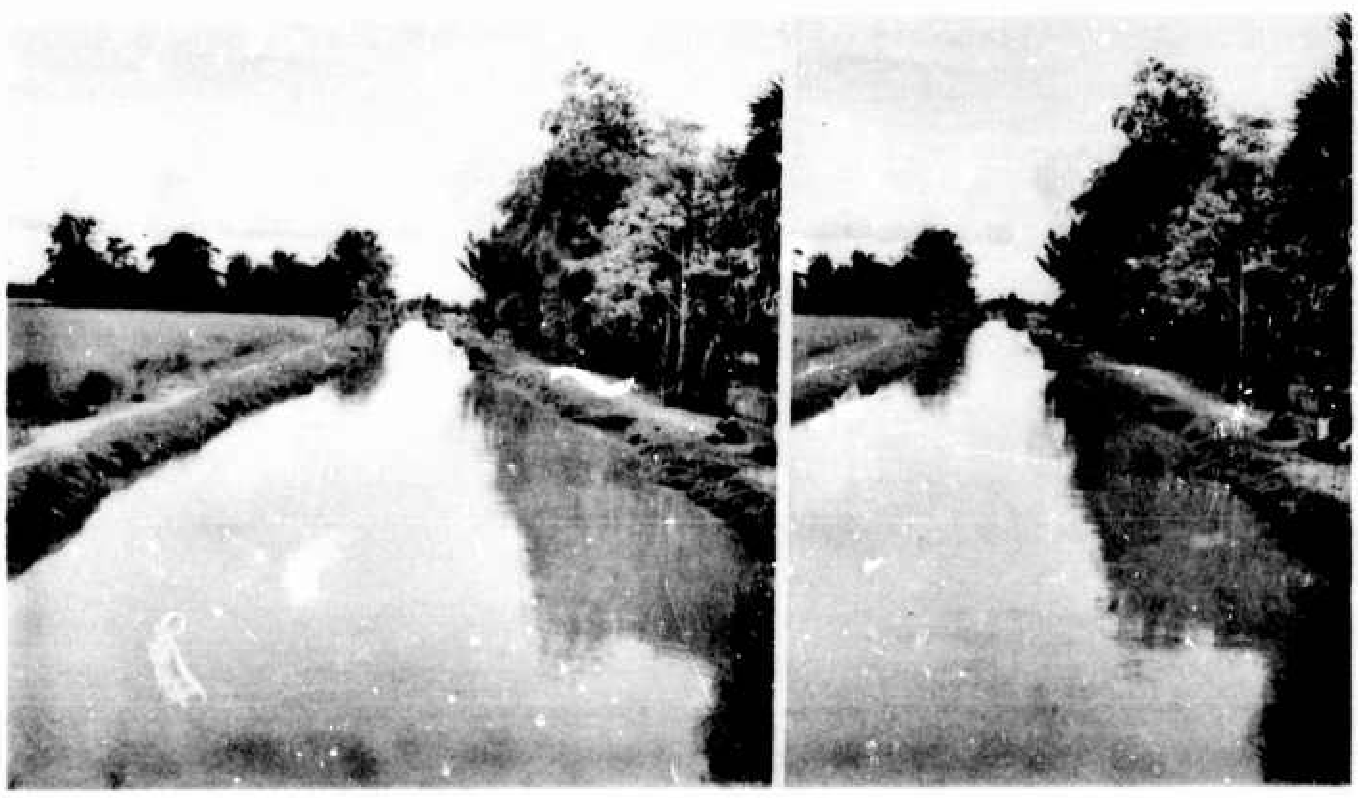


Fig. 215. Small canals and irrigation ditches--site 2-H-14-11 at location 2 in fig. 210, view southward (September 1964)

Fig. 216. Small canals and irrigation ditches--site 2-H-14-10 at location 3 in fig. 210, view to northeast (September 1964)

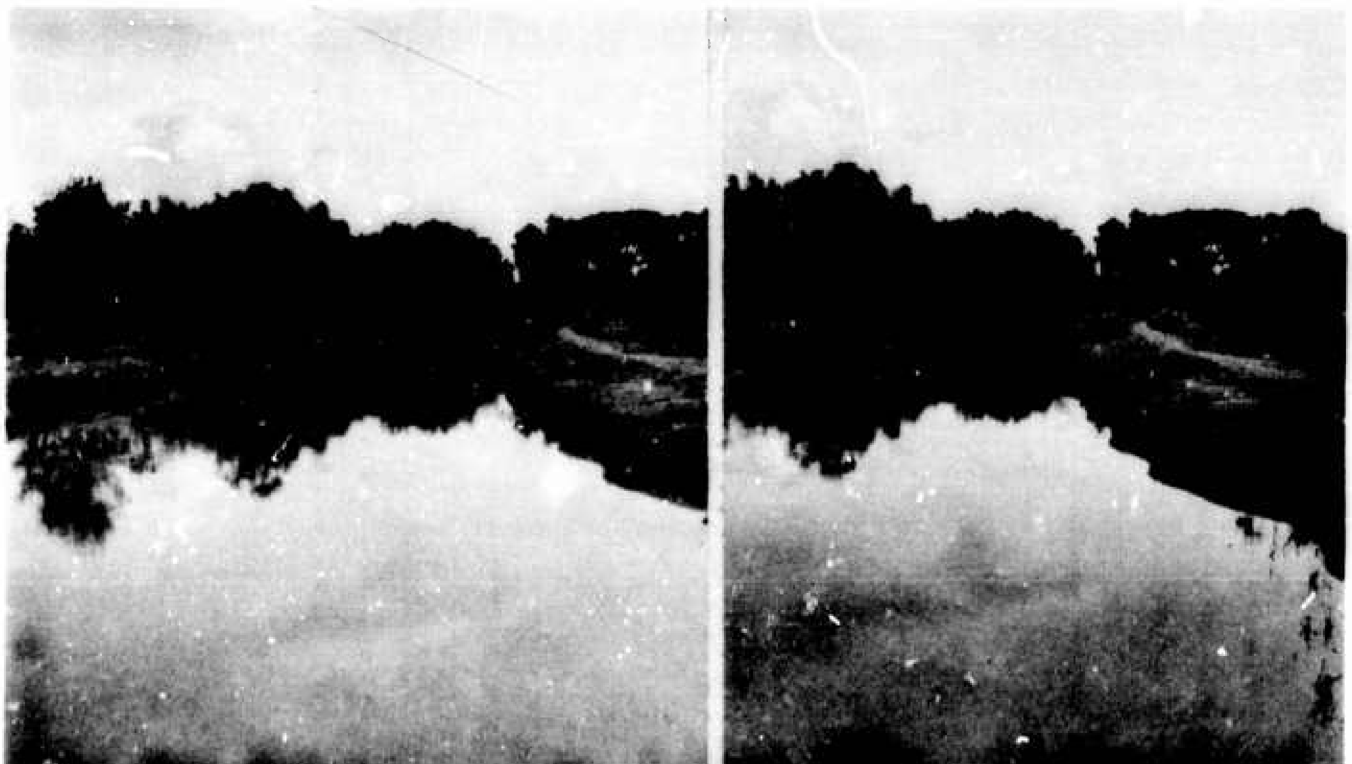


Fig. 217. Small canals and irrigation ditches--site 2-H-14-10 at location 3 in fig. 210, view to southwest (September 1964)

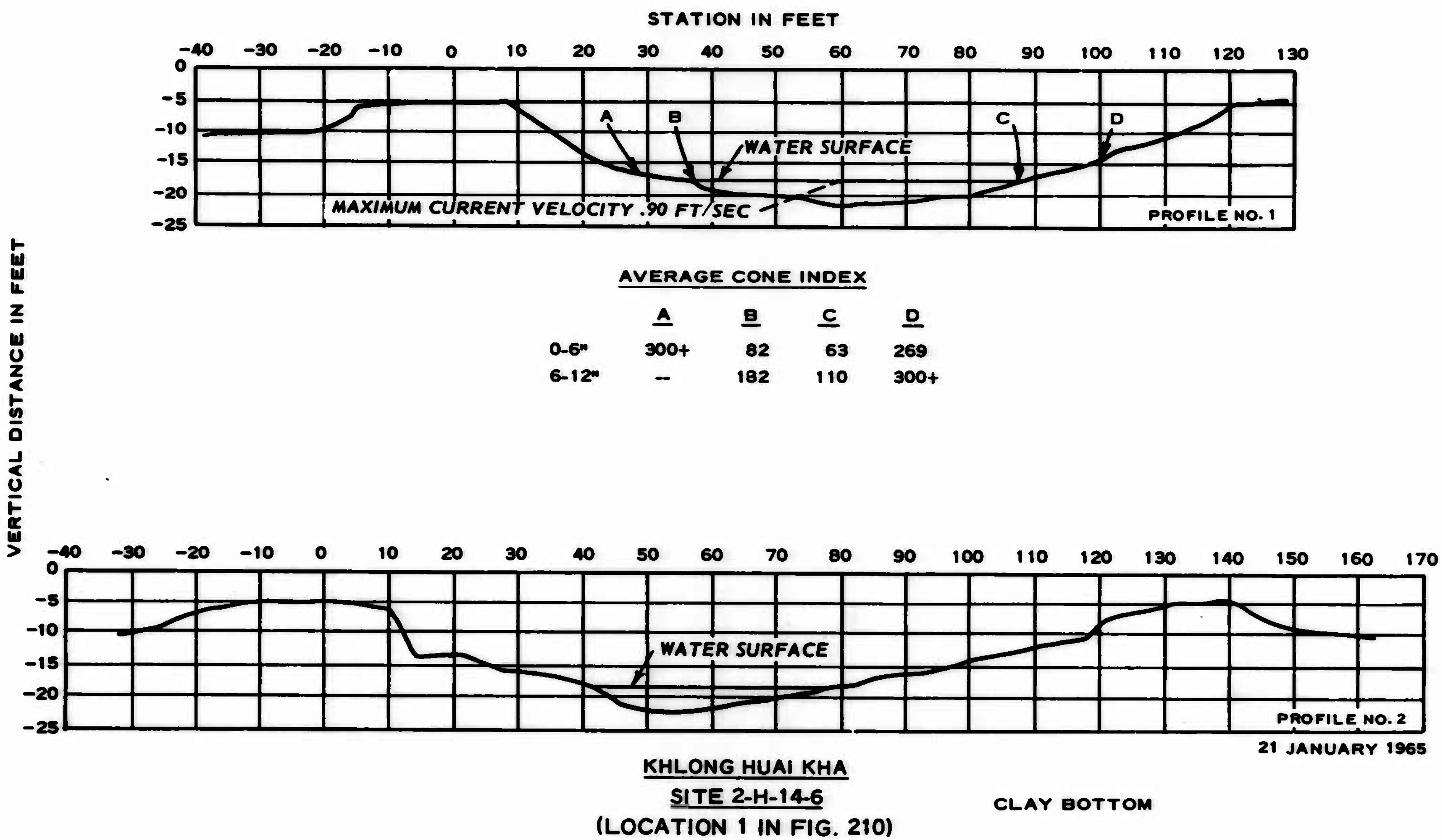
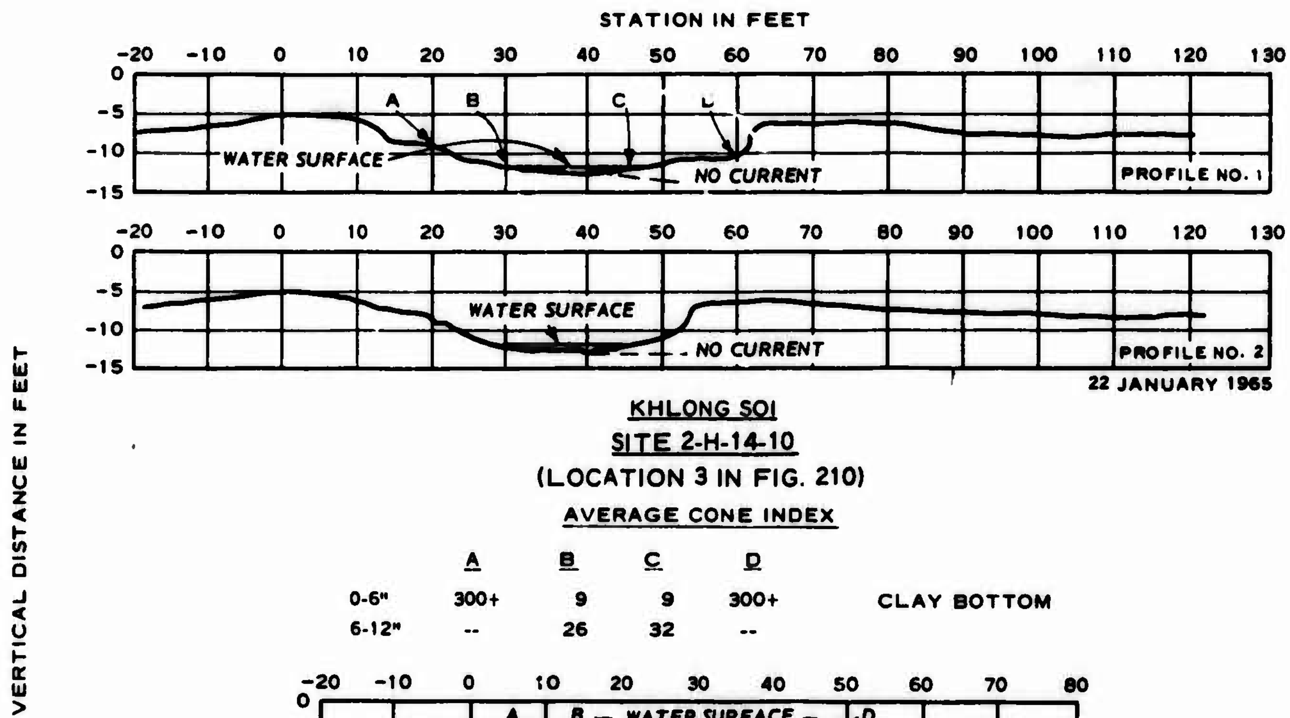


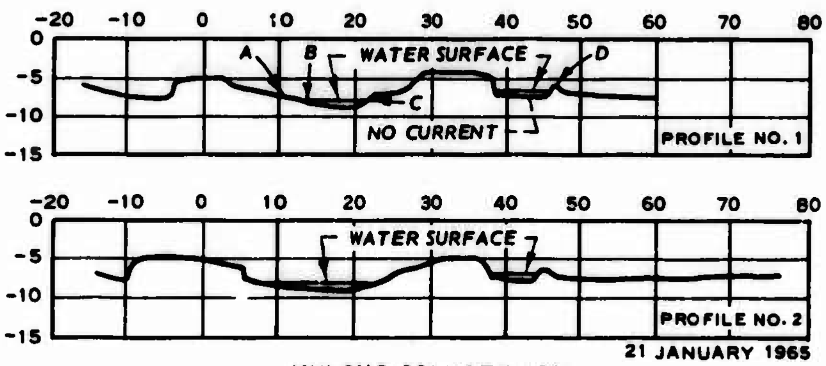

Fig. 218. Small canals and irrigation ditches--cross sections of small canal shown in figs. 212 and 213




KHLONG SOI
SITE 2-H-14-10
(LOCATION 3 IN FIG. 210)

AVERAGE CONE INDEX

| | A | B | C | D | |
|---|---|---|---|---|---|
| 0-6" | 300+ | 9 | 9 | 300+ | CLAY BOTTOM |
| 6-12" | -- | 26 | 32 | -- | |




KHLONG SOI YAEK I SAI
SITE 2-H-14-11
(LOCATION 2 IN FIG. 210)

AVERAGE CONE INDEX

| | A | B | C | D | |
|---|---|---|---|---|---|
| 0-6" | 300+ | 300+ | 300+ | 300+ | CLAY BOTTOM |
| 6-12" | -- | -- | -- | -- | |

Fig. 219. Small canals and irrigation ditches--cross sections of small canals shown in figs. 214-217

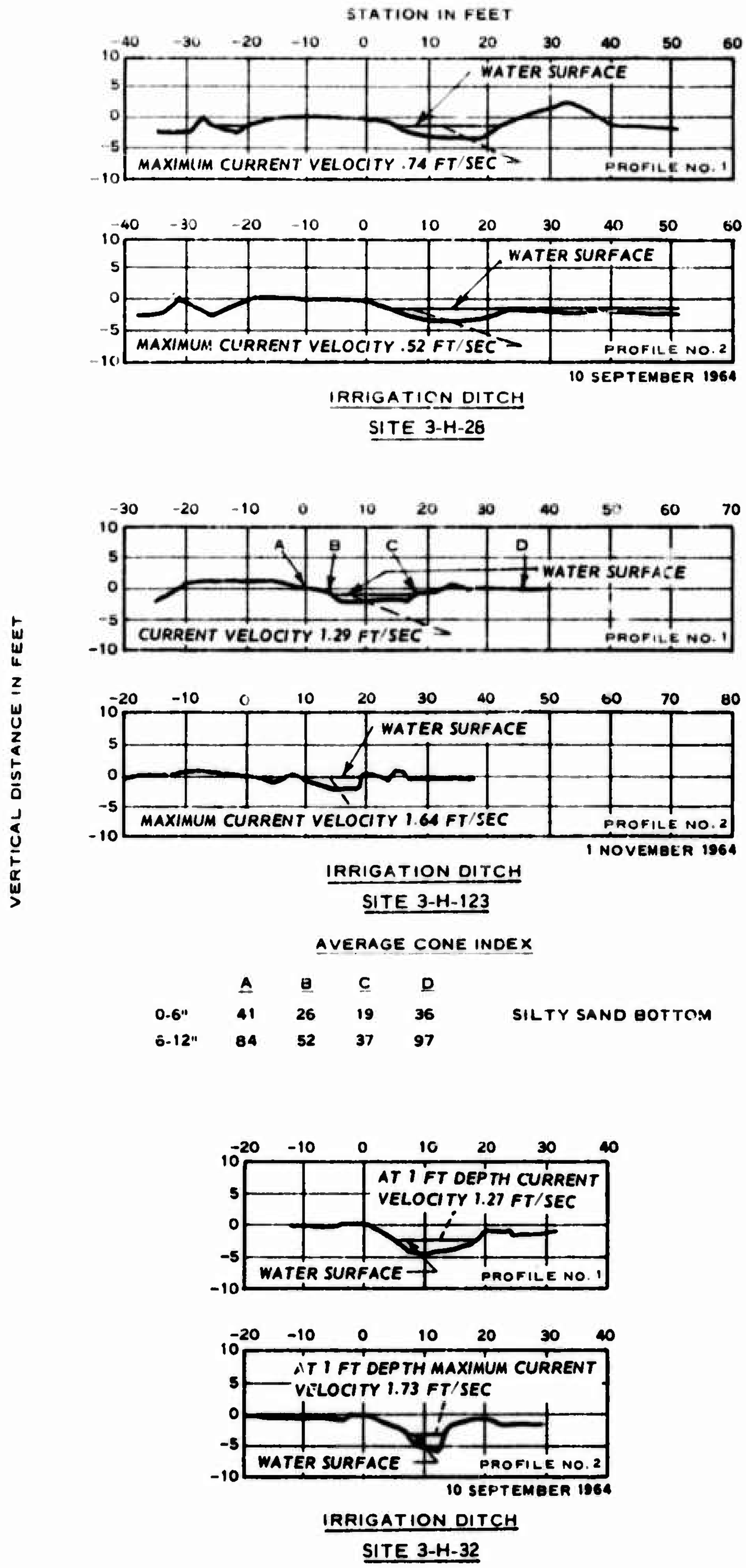



Fig. 220. Small canals and irrigation ditches--cross sections of irrigation ditches in the Chiang Mai area

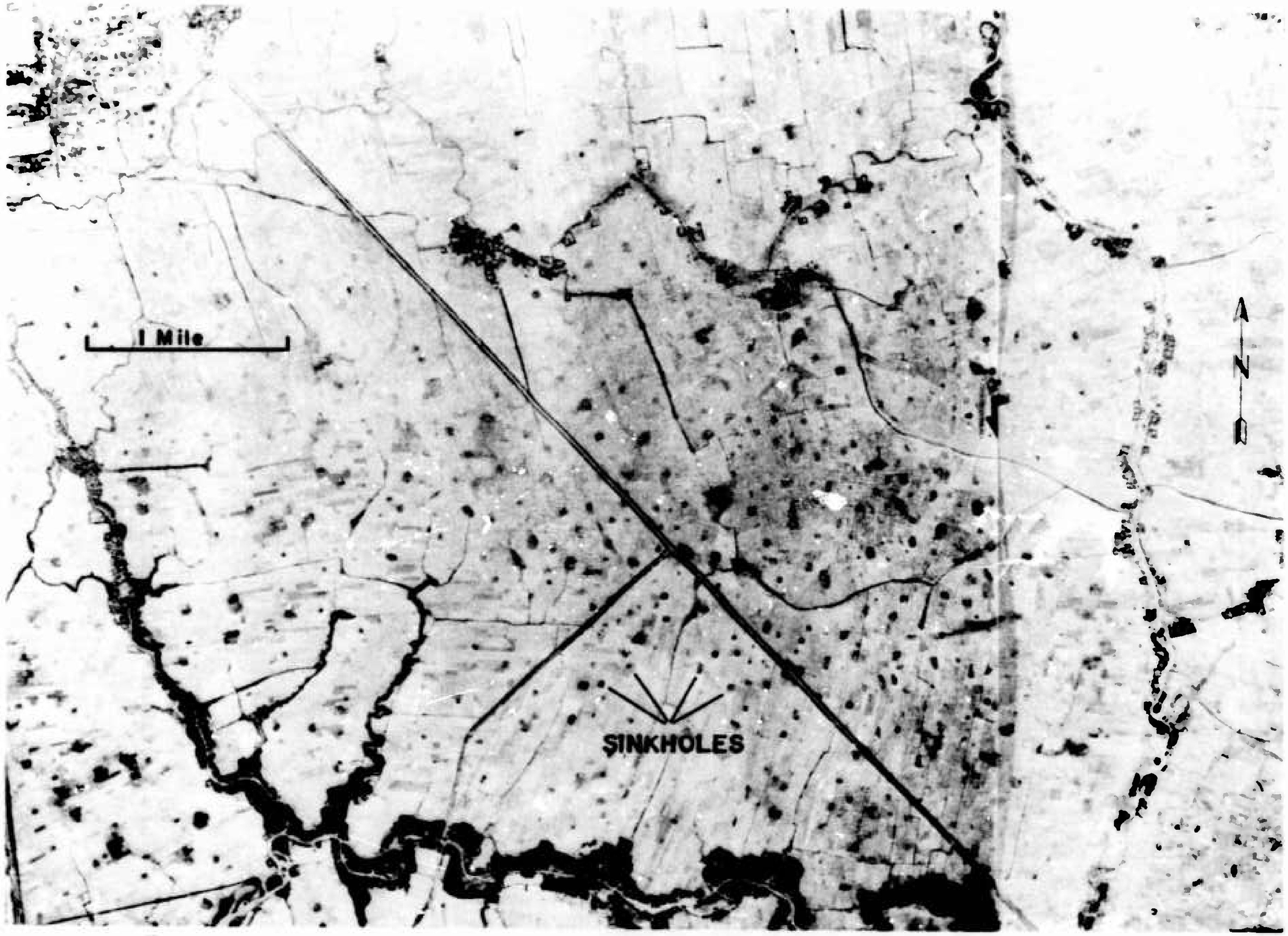



Fig. 221. Sinkhole pond pattern southeast of Ayutthaya (January 1953)

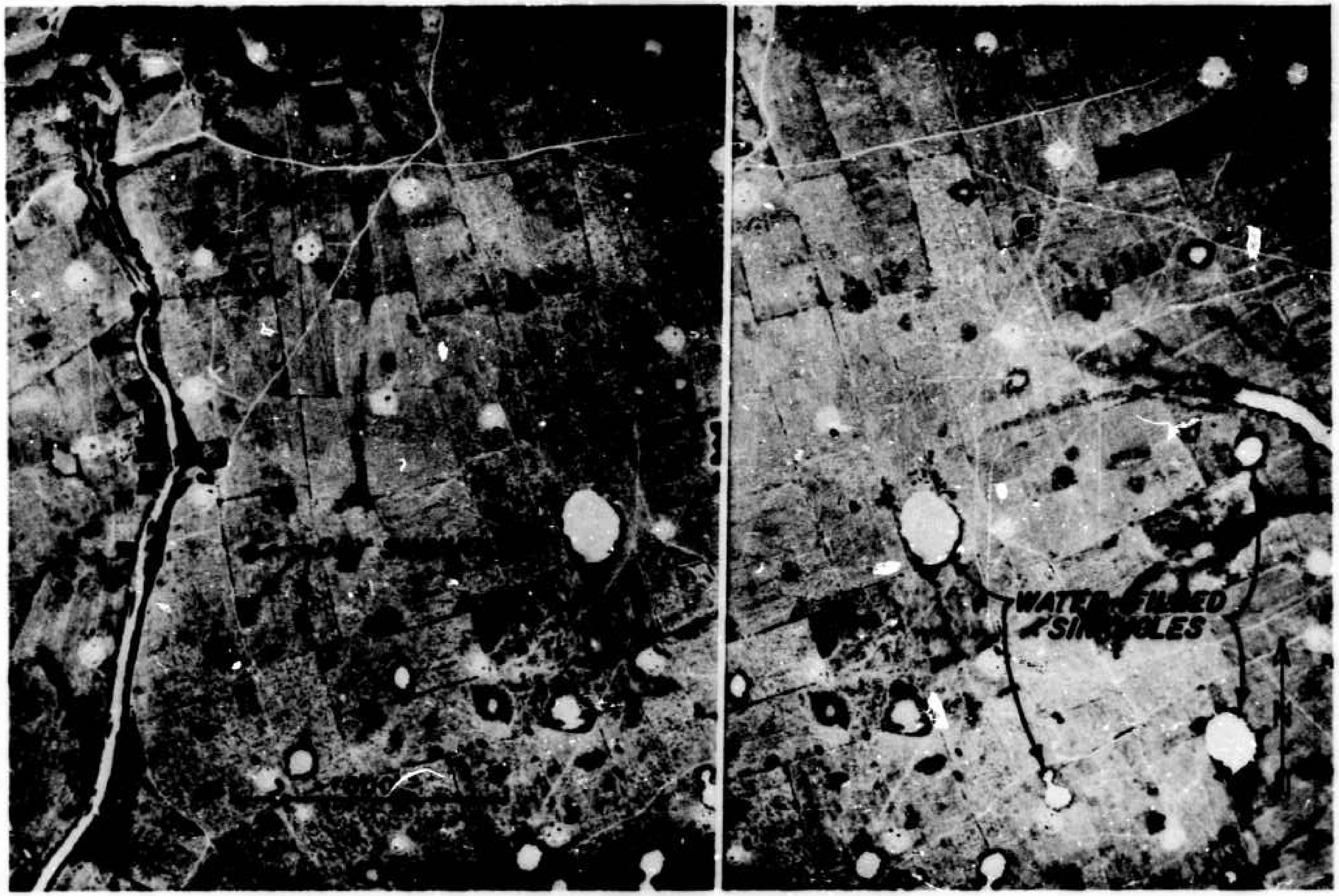


Fig. 222. Sinkhole pond pattern in Nakhon Sawan (February 1965)

Fig. 223. Sinkhole ponds, relatively dry, north of the Lop Buri study area (September 1964)


Fig. 224. Sinkhole pond southeast of Ayutthaya. Sinkhole is identified by dark-toned vegetation in center of photo just below the horizon. Water-filled borrow pit is in foreground (September 1964)

Fig. 225. Sinkhole pond shown in fig. 224, view from edge of sinkhole. Water in foreground exists in the center of the sinkhole (September 1964)


Fig. 226. Small stream pattern in Chiang Mai showing locations where hydrologic geometry data were acquired (January 1954)

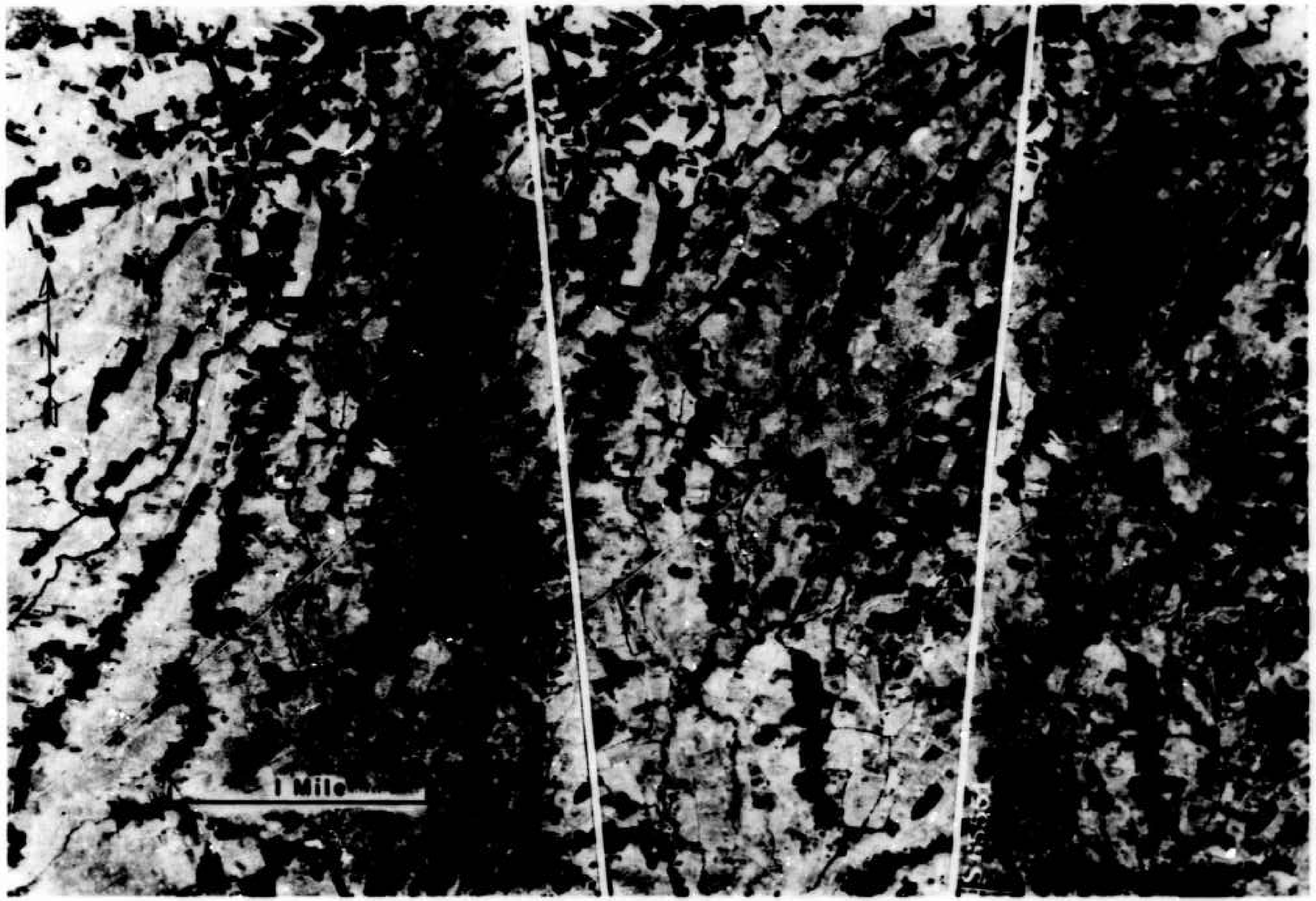
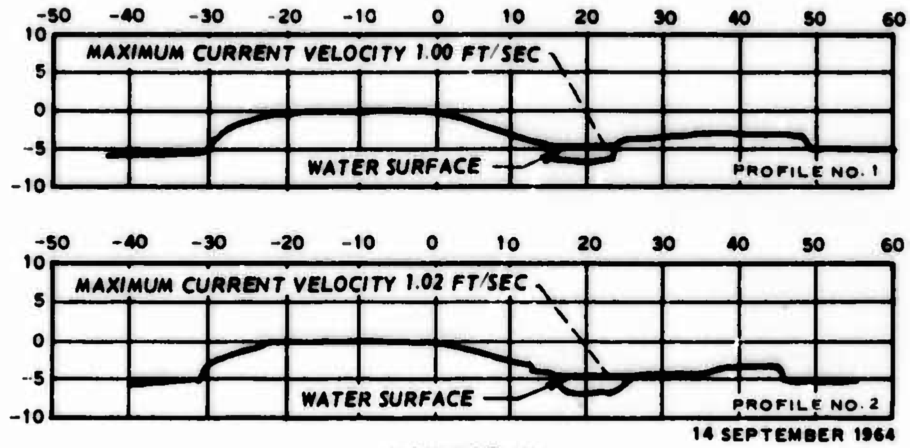


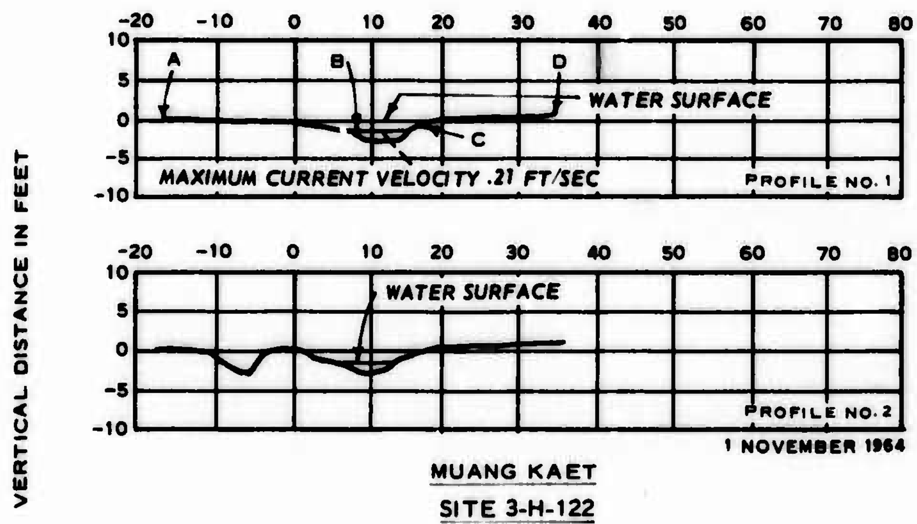

Fig. 227. Small streams--stereotriplet of a portion of fig. 226 (January 1954)




NAM MAE DU

SITE 3-H-40

(LOCATION 1 IN FIG. 226)



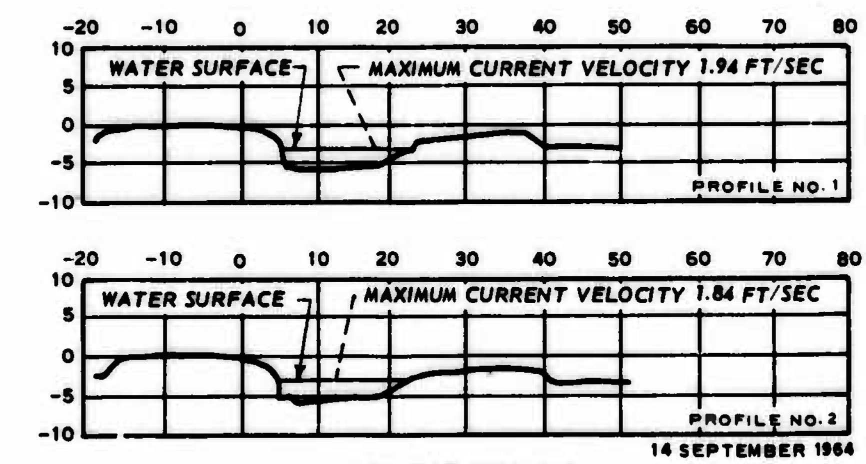

MUANG KAET

SITE 3-H-122

(LOCATION 2 IN FIG. 226)

AVERAGE CONE INDEX

| | A | B | C | D | |
|---|---|---|---|---|---|
| 0-6" | 82 | 39 | 23 | 81 | SILTY SAND BOTTOM |
| 6-12" | 118 | 65 | 83 | 118 | |




NAM MAE KWAUNG

SITE 3-H-39

(LOCATION 3 IN FIG. 226)

Fig. 228. Small streams--cross sections of small streams at locations 1, 2, and 3 in fig. 226

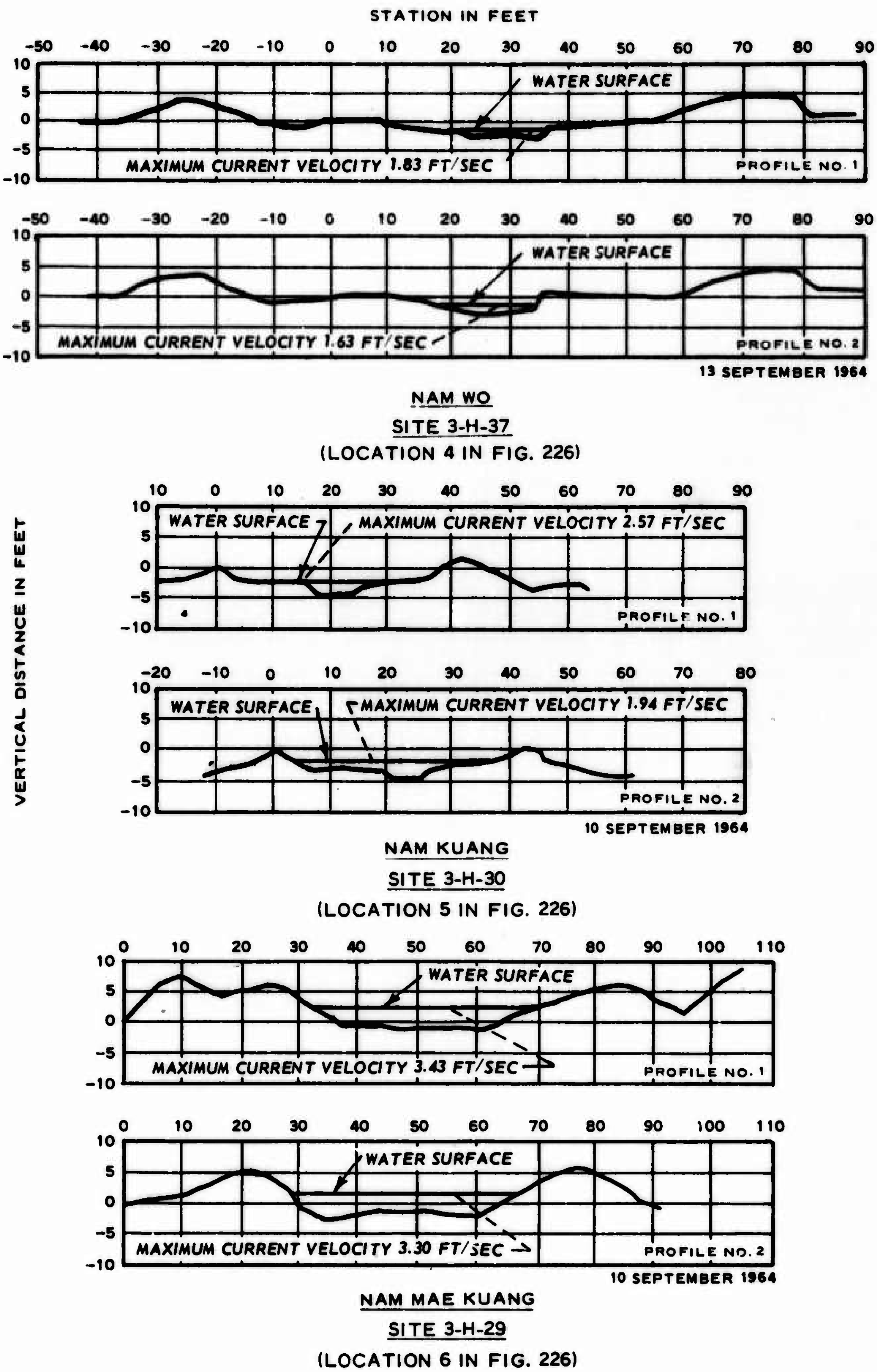



Fig. 229. Small streams--cross sections of small streams at locations 4, 5, and 6 in fig. 226

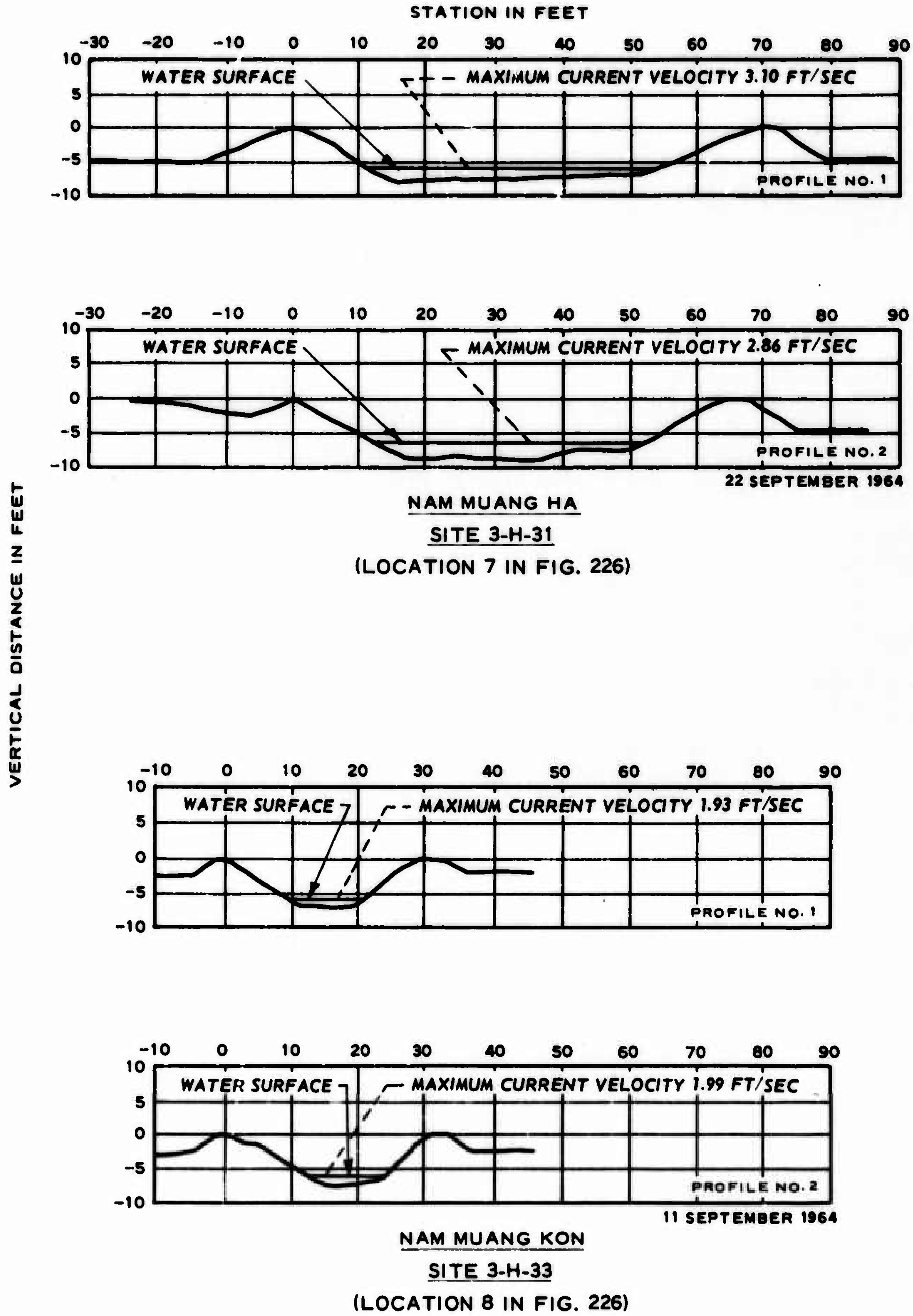



Fig. 230. Small streams--cross sections of small streams at locations 7 and 8 in fig 226

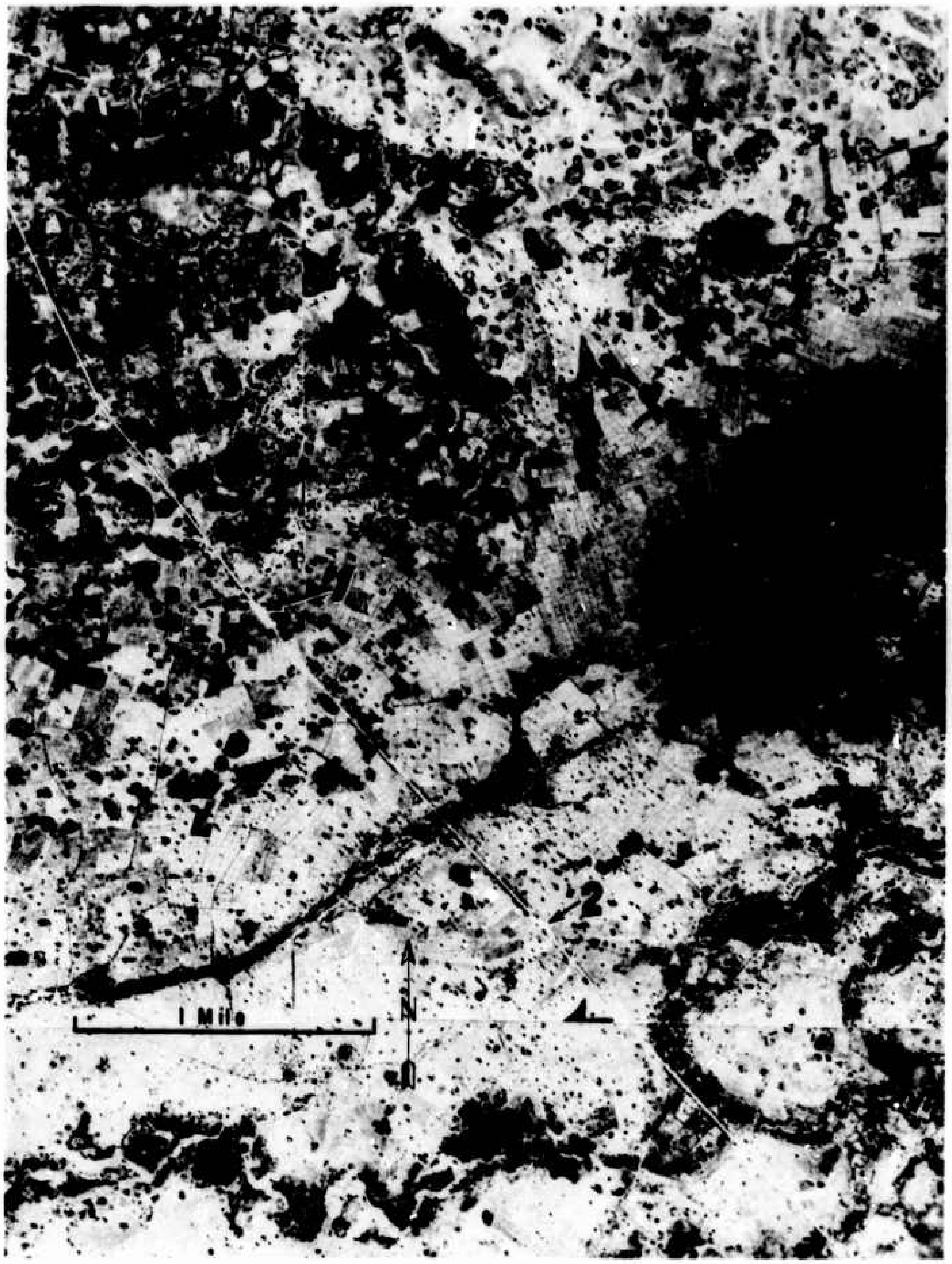



Fig. 231. Borrow pits and associated roadway in the Nakhon Sawan area showing locations of sites (1) 1-H-32 and (2) 1-H-27 (December 1953)

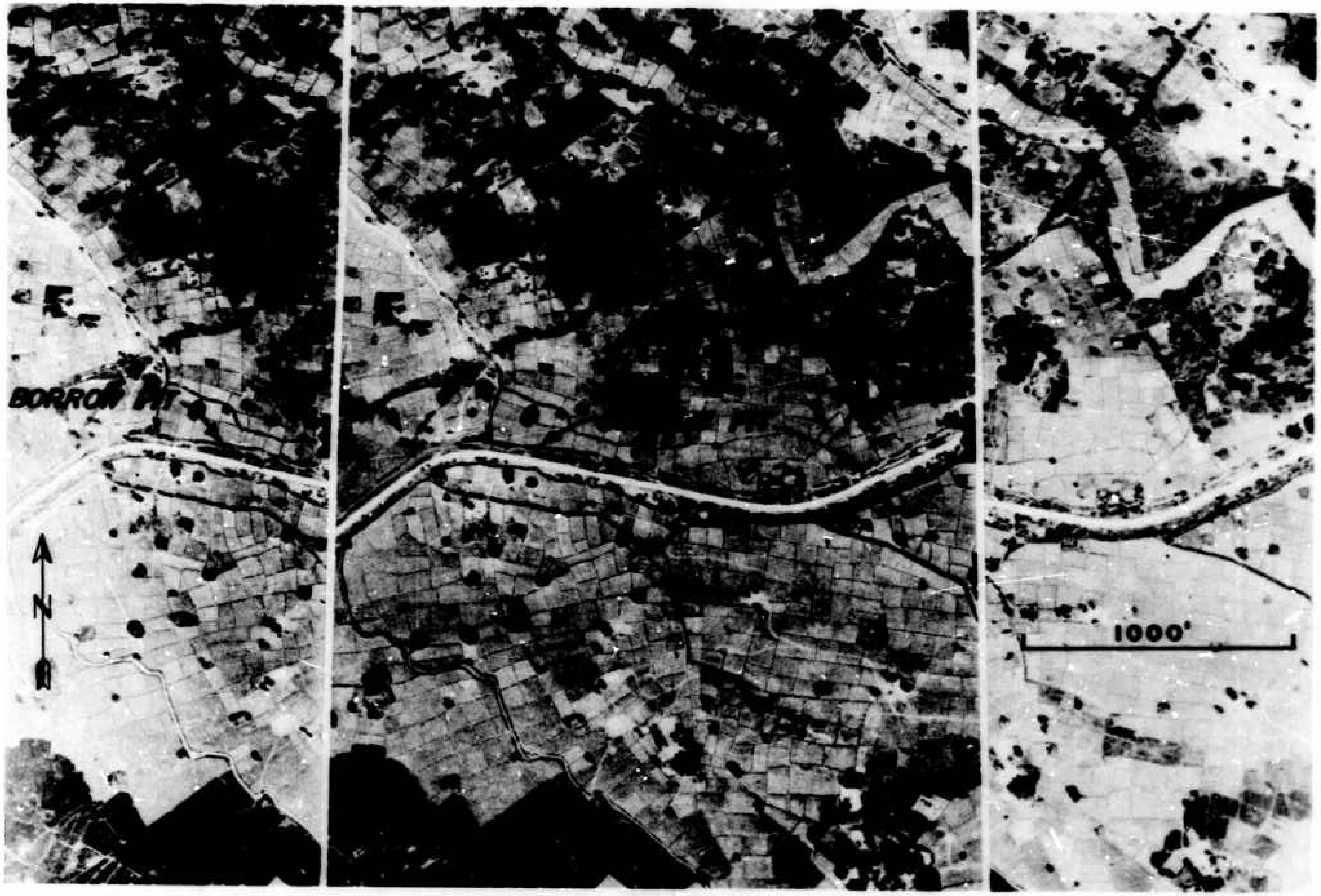



Fig. 232. Borrow pits--panchromatic stereotriplet of a section of roadway and adjacent borrow pits in the Nakhon Sawan area (February 1965)


Fig. 233. Borrow pits--infrared mosaic of a section of roadway and adjacent borrow pits in the Nakhon Sawan area (February 1965)

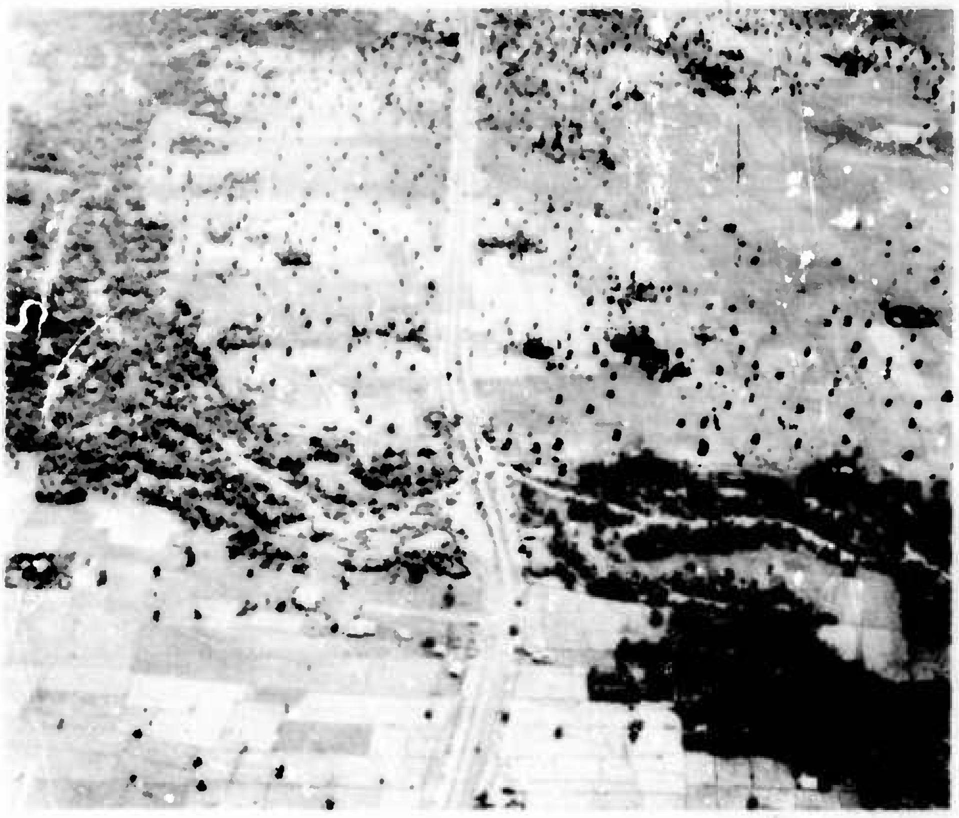


Fig. 234. Borrow pit and roadway complex in the Lop Buri area (October 1964)

Fig. 235. Borrow pit in the Lop Buri area (site HG-14-3). A cross section of this site is shown in fig. 238 (September 1964)

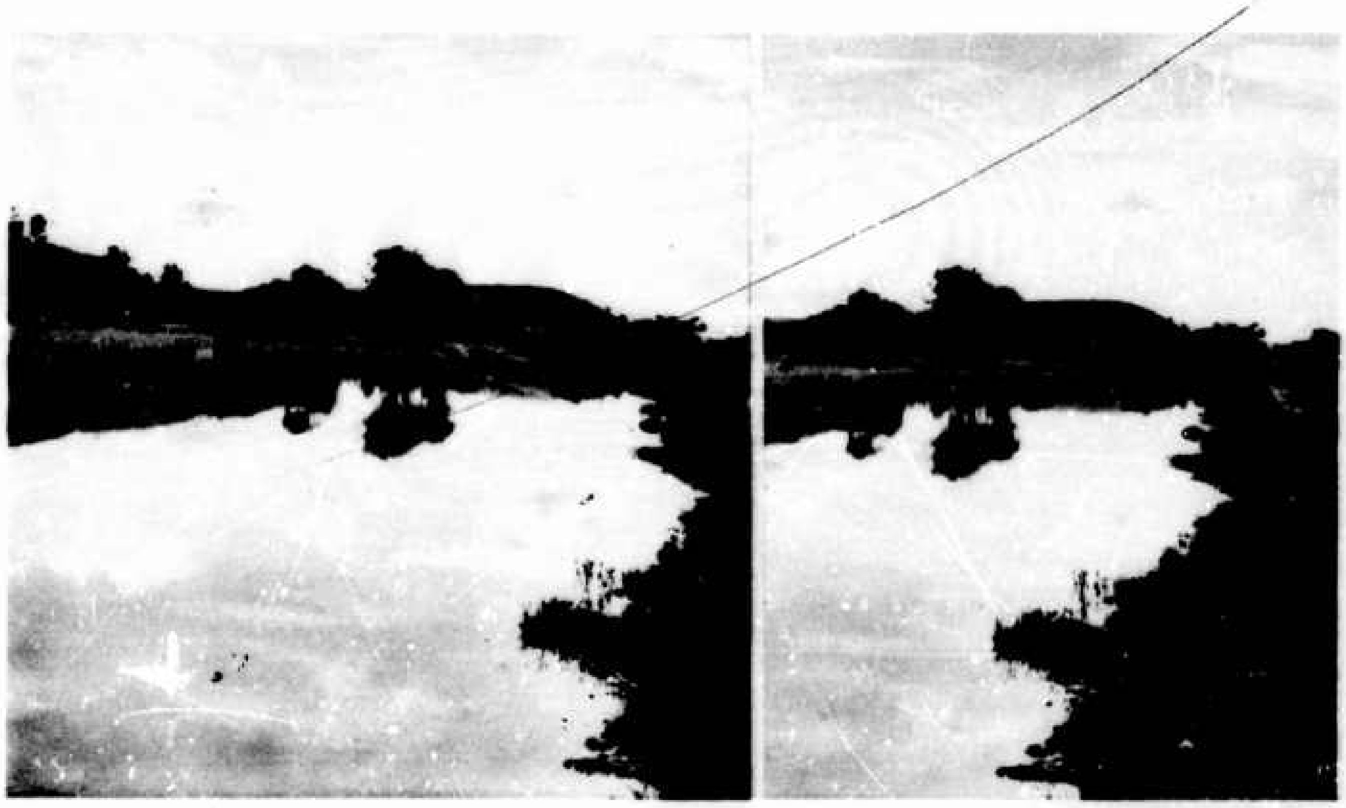
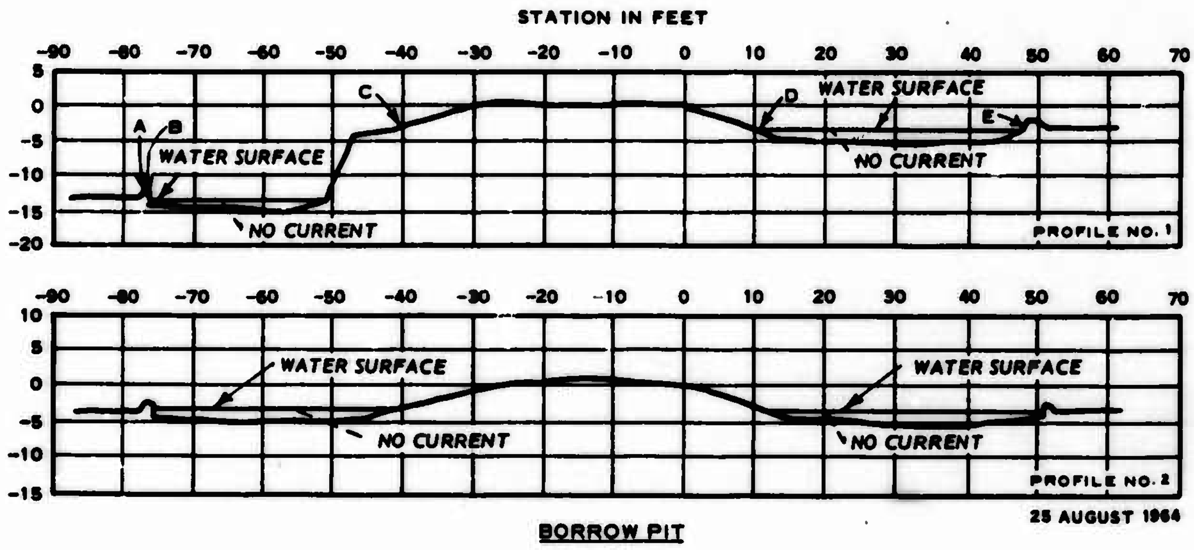


Fig. 236. Borrow pit at site HG-14-1 in the Lop Buri area (September 1964)

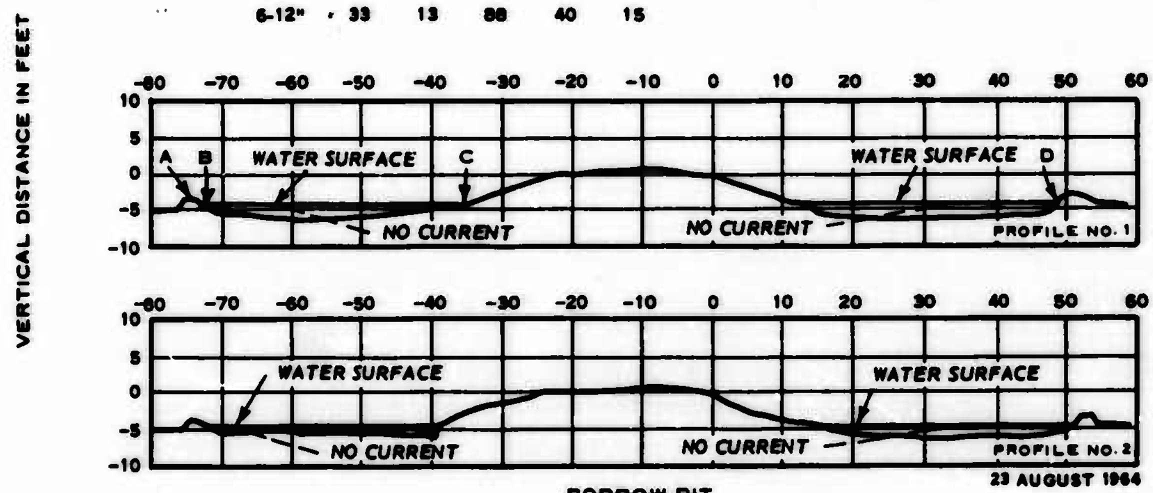
Fig. 237. Borrow pit in the Lop Buri area showing the depth of water generally present in these features (September 1964)




BORROW PIT
SITE 1-H-32
(LOCATION 1 IN FIG. 231)

AVERAGE CONE INDEX

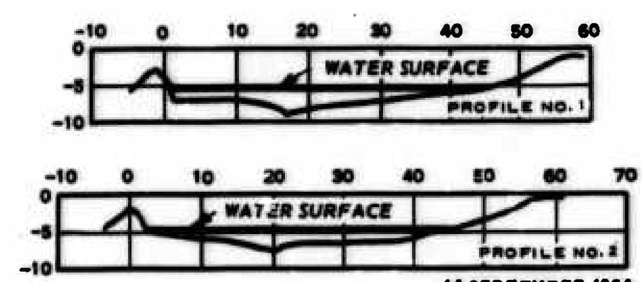
| | A | B | C | D | E | |
|---|---|---|---|---|---|---|
| 0-6" | 39 | 15 | 41 | 15 | 9 | SAND AND CLAY BOTTOM |
| 6-12" | 33 | 13 | 88 | 40 | 15 | |




BORROW PIT
SITE 1-H-27
(LOCATION 2 IN FIG. 231)

AVERAGE CONE INDEX

| | A | B | C | D | |
|---|---|---|---|---|---|
| 0-6" | 30 | 8 | 80 | 17 | SAND AND CLAY BOTTOM |
| 6-12" | 65 | 25 | 132 | 33 | |




BORROW PIT
SITE HG-14-3

Fig. 238. Borrow pits--cross sections of borrow pits in the Nakhon Sawan and Lop Buri areas

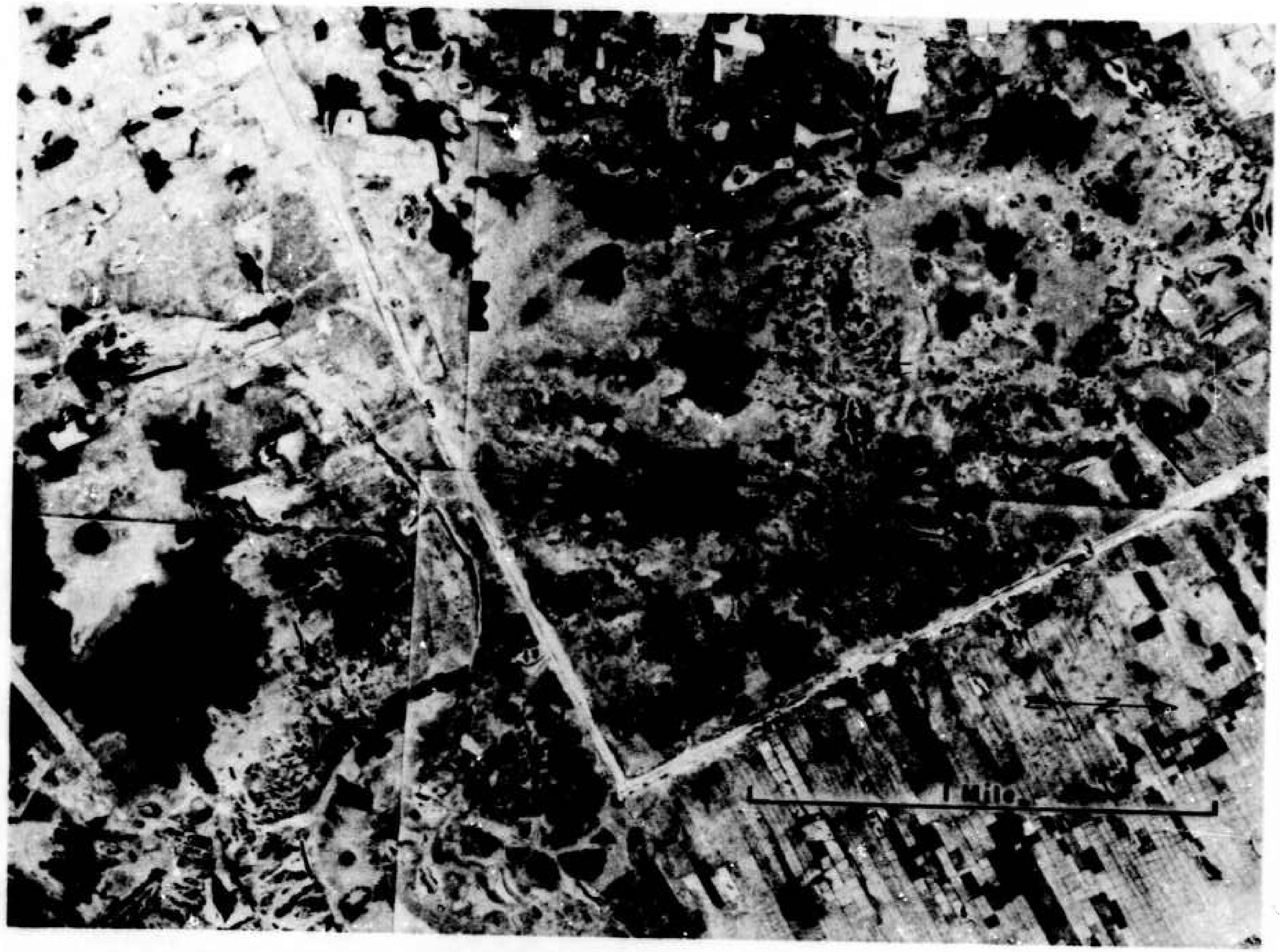



Fig. 239. Swamp area in Lop Buri being taken over by cultivation practices (December 1964)

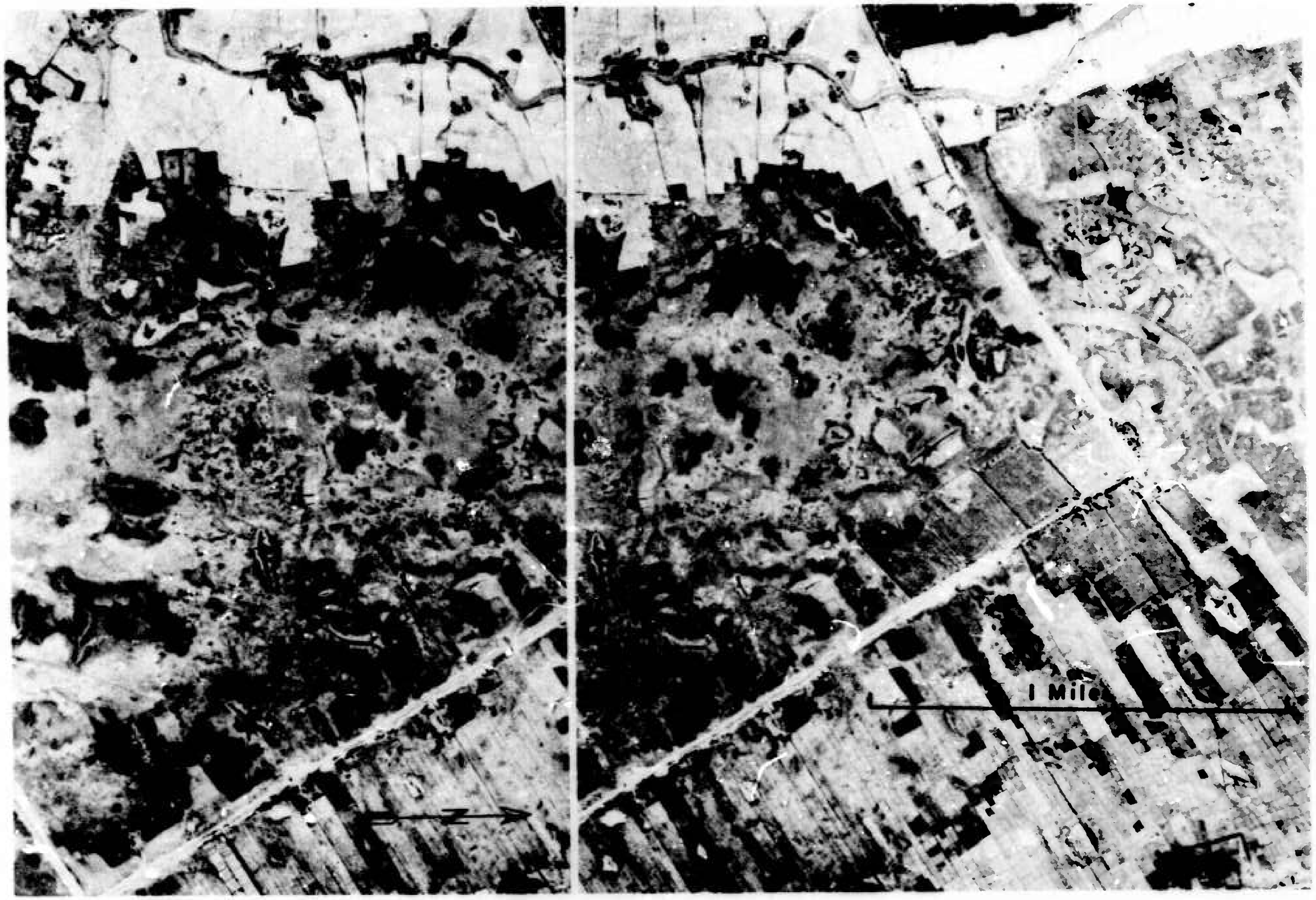



Fig. 240. Swamps--stereopair of the swamp area presented in fig. 239 (December 1964)

Fig. 241. Swamp area in Nakhon Sawan
(September 1964)

Fig. 242. Swamp in the Lop Buri area
(September 1964)


Fig. 243. Mountain streams--aerial mosaic of an area of mountainous terrain in Chanthaburi showing the pattern of mountain streams and the locations where hydrologic geometry data were acquired (February 1953)

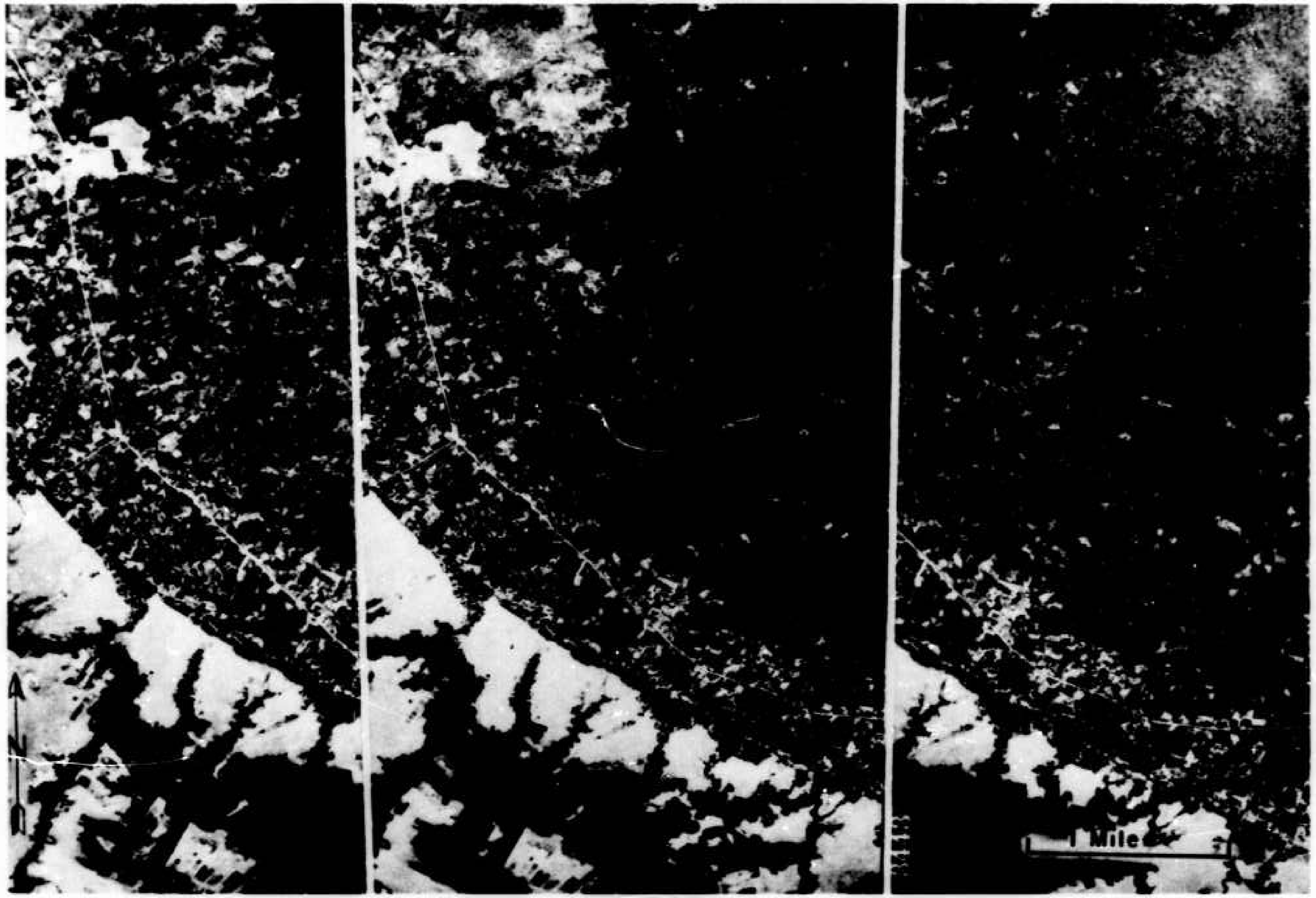



Fig. 244. Mountain streams--stereotriplet of a section of fig. 243 (February 1953)

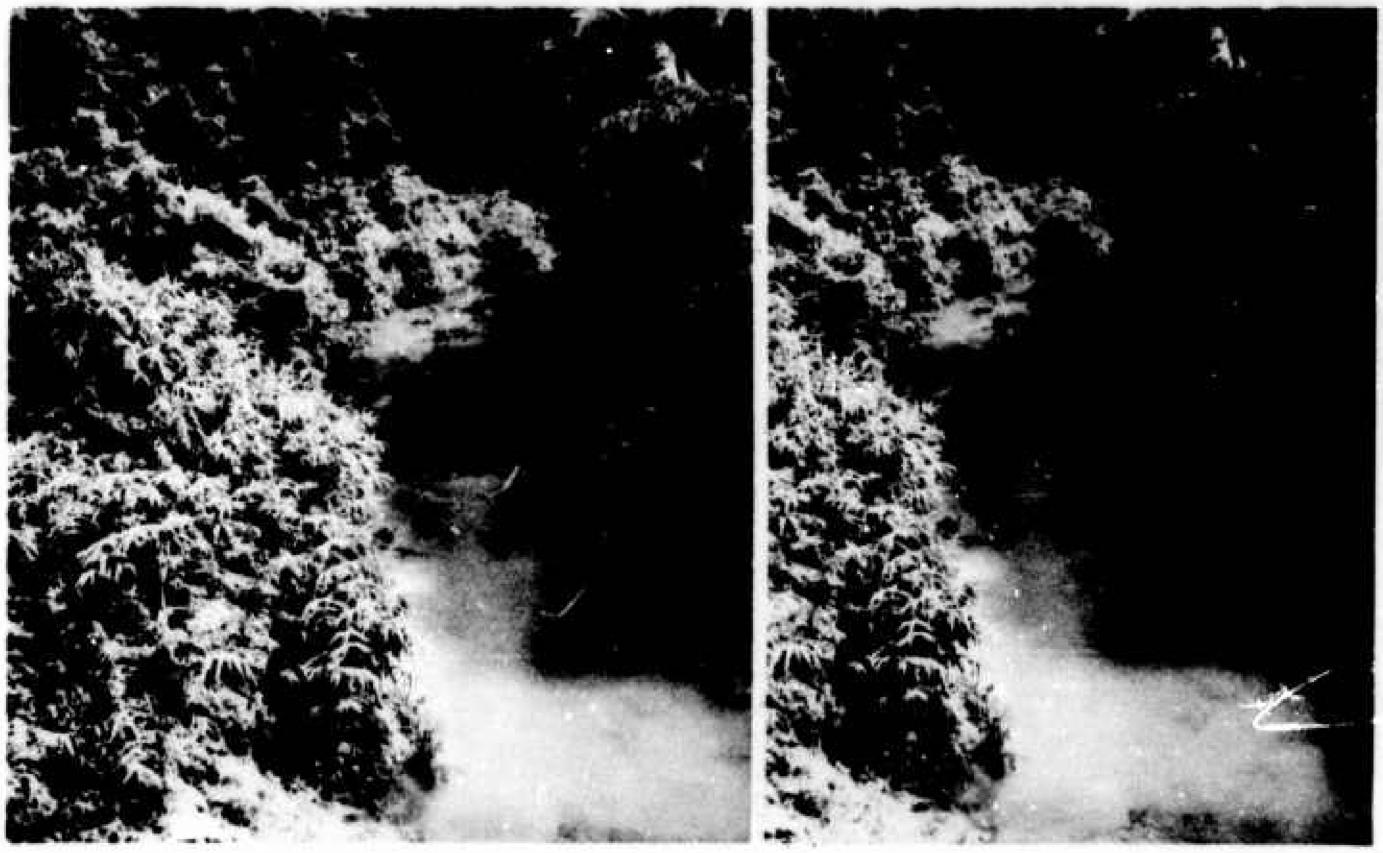


Fig. 245. Mountain stream at site HG-11-3 near Chanthaburi, location 1 in fig. 243 (October 1964)

Fig. 246. Mountain stream at site HG-11-5 near Chanthaburi, location 2 in fig. 243 (October 1964)

Fig. 247. Mountain stream at site HG-15-8 near Chanthaburi, location 3 in fig. 243 (October 1964)

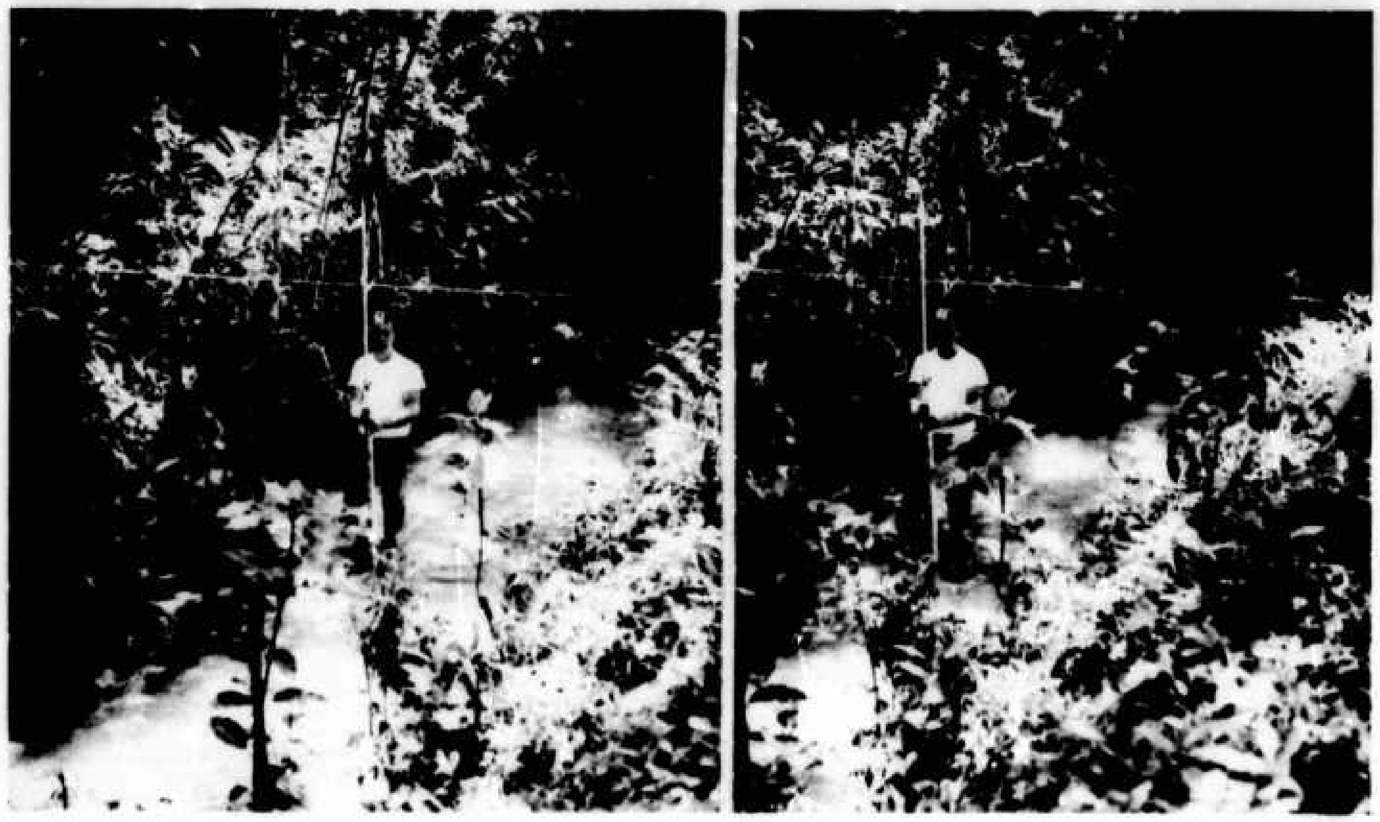


Fig. 248. Mountain stream at site HG-17-4 near Chanthaburi, location 4 in fig. 243 (October 1964)

Fig. 249. Mountain stream at site HG-17-5 near Chanthaburi, location 5 in fig. 243 (October 1964)

Fig. 250. Mountain stream at site HG-17-9 near Chanthaburi, location 6 in fig. 243 (October 1964)

Fig. 251. Mountain stream at site HG-17-8 near Chanthaburi, location 7 in fig. 243 (October 1964)

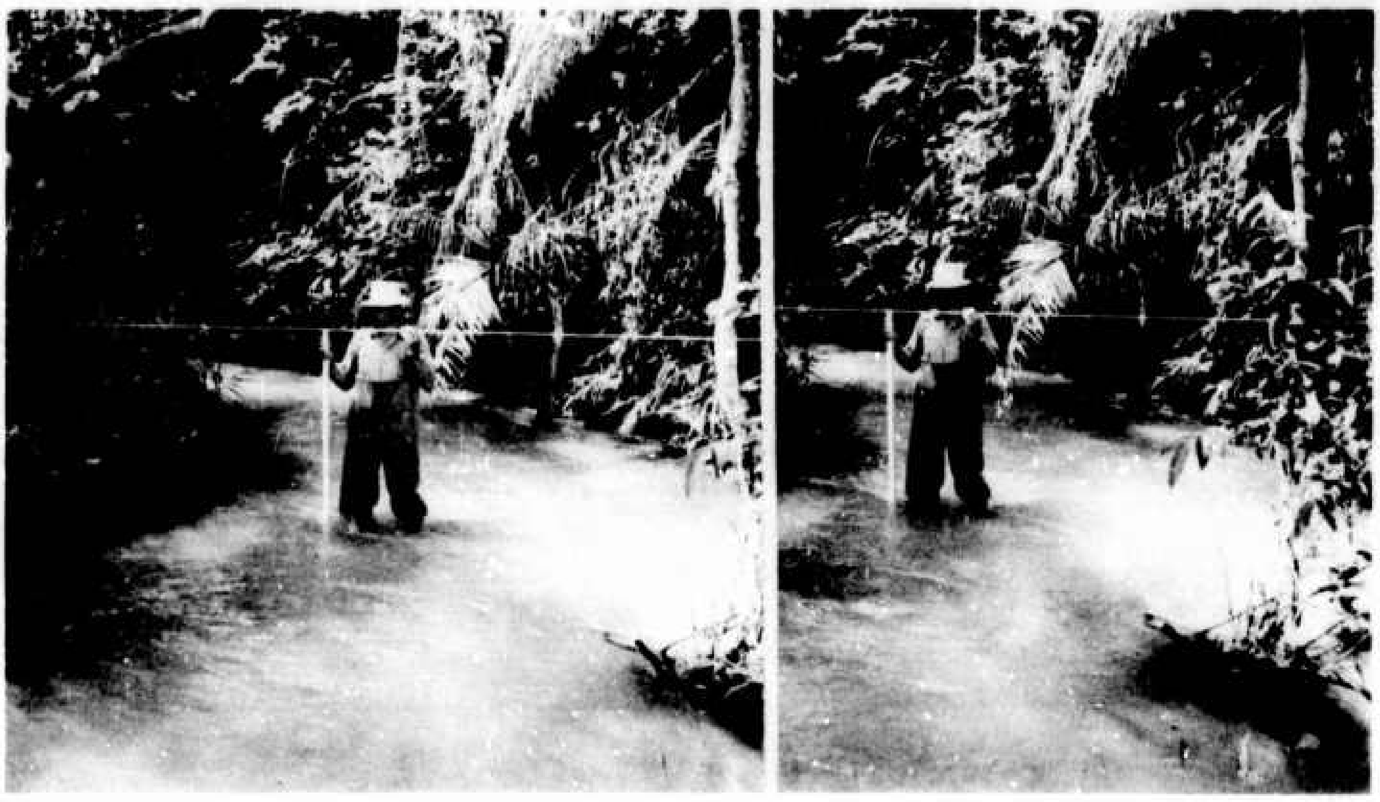


Fig. 252. Mountain stream at site HG-9-5 near Chanthaburi (October 1964)

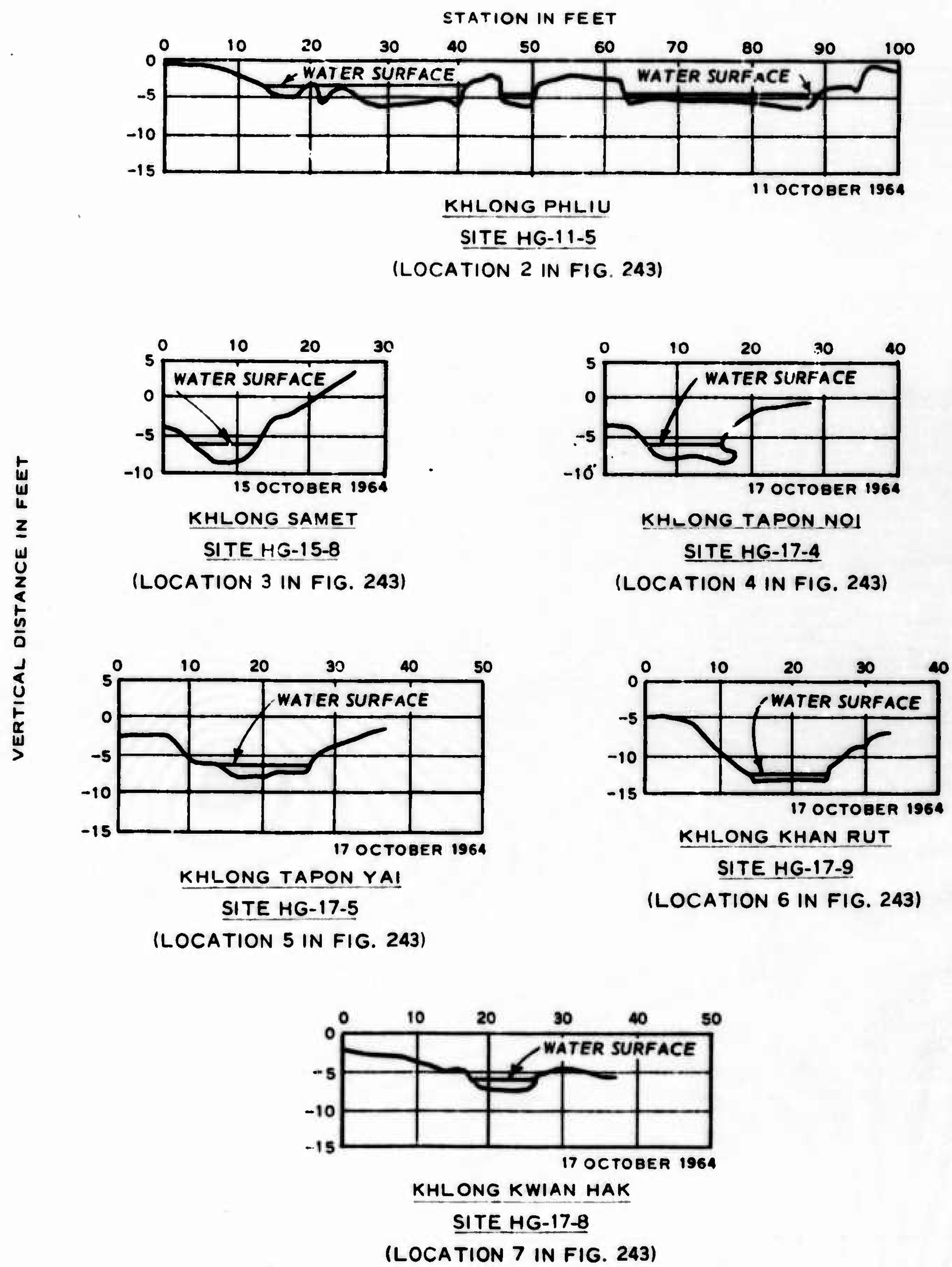



Fig. 253. Mountain streams--cross sections of streams at locations 2-7 in fig. 243

COMPARATIVE PHOTOGRAPHY

Table 6

Comparative Photography Flight Lines

**Area 1, Nakhon Sawan**

| Line No. | Grid Coordinates 1:50,000 Maps* | | Length Miles |
|---|---|---|---|
| NS-1 | 607356 | 805426 | 49.2 |
| NS-2 | 940470 | 525232 | 38.5 |
| NS-3 | 210460 | 210155 | 18.6 |
| NS-4 | 440380 | 375200 | 11.8 |
| NS-5 | 380495 | 279230 | 17.6 |
| | | | 135.7 |

**Area 2, Lop Buri**

| Line No. | Grid Coordinates 1:50,000 Maps* | | Length Miles |
|---|---|---|---|
| LB-1 | 675835 | 633475 | 40.5 |
| LB-2 | 740520 | 774373 | 9.5 |
| LB-4 | 640370 | 844361 | 12.8 |
| LB-6 | 848104 | 965345 | 17.8 |
| LB-7 | 990263 | 122963 | 20.0 |
| LB-8 | 899104 | 061081 | 10.0 |
| LB-11 | 840967 | 090927 | 15.7 |
| LB-12 | 899947 | 032818 | 11.5 |
| LB-13 | 854740 | 112905 | 19.0 |
| | | | 156.8 |

**Area 3, Chiang Mai**

| Line No. | Grid Coordinates 1:50,000 Maps* | | Length Miles |
|---|---|---|---|
| CM-1 | 190890 | 970750 | 15.8 |
| CM-2 | 950792 | 210690 | 16.8 |
| CM-3 | 045870 | 820455 | 28.8 |
| CM-4 | 938925 | 008755 | 11.3 |
| CM-5 | 258870 | 885455 | 34.0 |
| | | | 106.7 |

**Area 4, Pran Buri**

| Line No. | Grid Coordinates 1:50,000 Maps* | | Length Miles |
|---|---|---|---|
| PB-1 | 900809 | 930755 | 3.9 |
| PB-2 | 869778 | 900705 | 5.0 |
| PB-3 | 075765 | 827647 | 17.1 |
| PB-4 | 965725 | 935337 | 24.0 |
| PB-5 | 860440 | 120450 | 16.2 |
| PB-6 | 090450 | 972322 | 11.0 |
| | | | 77.2 |

**Area 5, Khon Kaen**

| Line No. | Grid Coordinates 1:50,000 Maps* | | Length Miles |
|---|---|---|---|
| KK-1 | 152251 | 953158 | 49.8 |
| KK-2 | 685190 | 644070 | 7.8 |
| KK-3 | 685190 | 690346 | 9.5 |
| KK-4 | 815251 | 815090 | 9.8 |
| | | | 76.9 |

**Area 6, Chanthaburi**

| Line No. | Grid Coordinates 1:50,000 Maps* | | Length Miles |
|---|---|---|---|
| CB-1 | 208976 | 125953 | 20.4 |
| CB-2 | 898960 | 196870 | 14.7 |
| CB-3 | 785825 | 961725 | 12.6 |
| CB-4 | 000110 | 955970 | 9.2 |
| CB-5 | 209112 | 975650 | 33.5 |
| CB-6 | 960030 | 874730 | 19.2 |
| CB-7 | 118960 | 012964 | 25.7 |
| | | | 135.3 |

**Area 7, Hat Yai**

| Line No. | Grid Coordinates 1:50,000 Maps* | | Length Miles |
|---|---|---|---|
| HY-1 | 367874 | 424740 | 9.2 |
| HY-2 | 793942 | 635740 | 15.8 |
| | | | 25.0 |

* Army Map Service, L708.

Table 7

Comparative Photography

Time Schedule of 1:5000-Scale Strip Photography

Completed as of 28 February 1965

| Area | Project Line No. | Contractor's Line No. | Film Type | Roll and Negative No. | Date (1965) | Time |
|---|---|---|---|---|---|---|
| Nakhon Sawan (Area 1) | 1 | 2 | Pan | 13-70 to 13-166 | 19 Jan | 1013 |
| | | | IR | 2-1 to 2-192 | 5 Feb | 1043 |
| | 2 | 1 | Pan | 12-207 to 13-67 | 19 Jan | 956 |
| Lop Buri (Area 2) | 8 | 4 | Pan | | | |
| | | | CD | | | |
| | 11 | 3 | Pan | 7-75 to 7-133 | 12 Feb | 1009 |
| | | | IR | 1-1 to 1-60 | 12 Feb | 1050 |
| | | | CD | 2-1 to 2-61 | 16 Feb | 1128 |
| | 12 | 2 | Pan | 7-134 to 7-182 | 12 Feb | 1020 |
| | | | IR | 1-61 to 1-106 | 12 Feb | 1157 |
| | | | CD | 3-1 to 3-50 | 16 Feb | 1152 |
| | 13 | 1 | Pan | 7-1 to 7-74 | 12 Feb | 1006 |
| | | | IR | 1-107 to 1-179 | 12 Feb | 1111 |
| | | | CD | 1-1 to 1-77 | 16 Feb | 1057 |

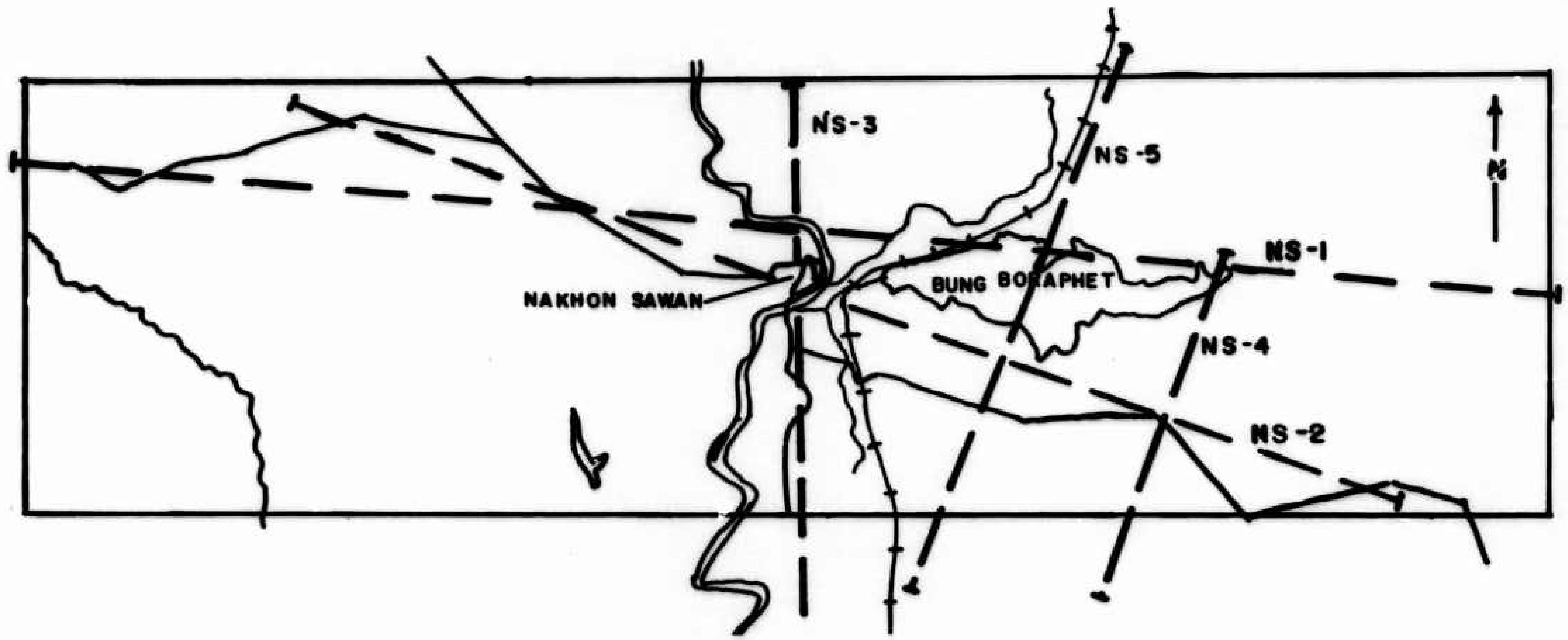



Fig. 254. Comparative photography flight lines, Nakhon Sawan, study area 1

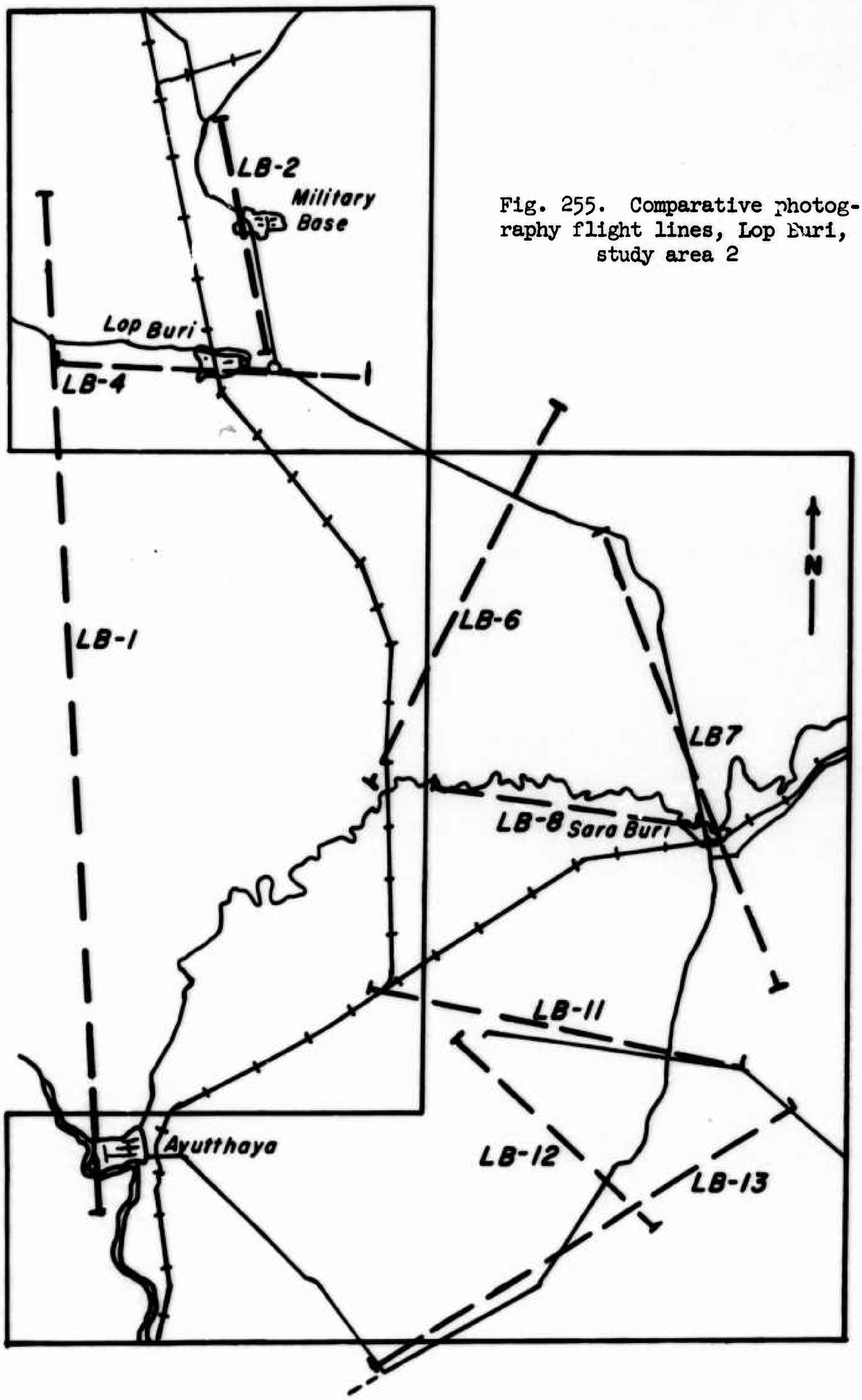



Fig. 255. Comparative photography flight lines, Lop Buri, study area 2

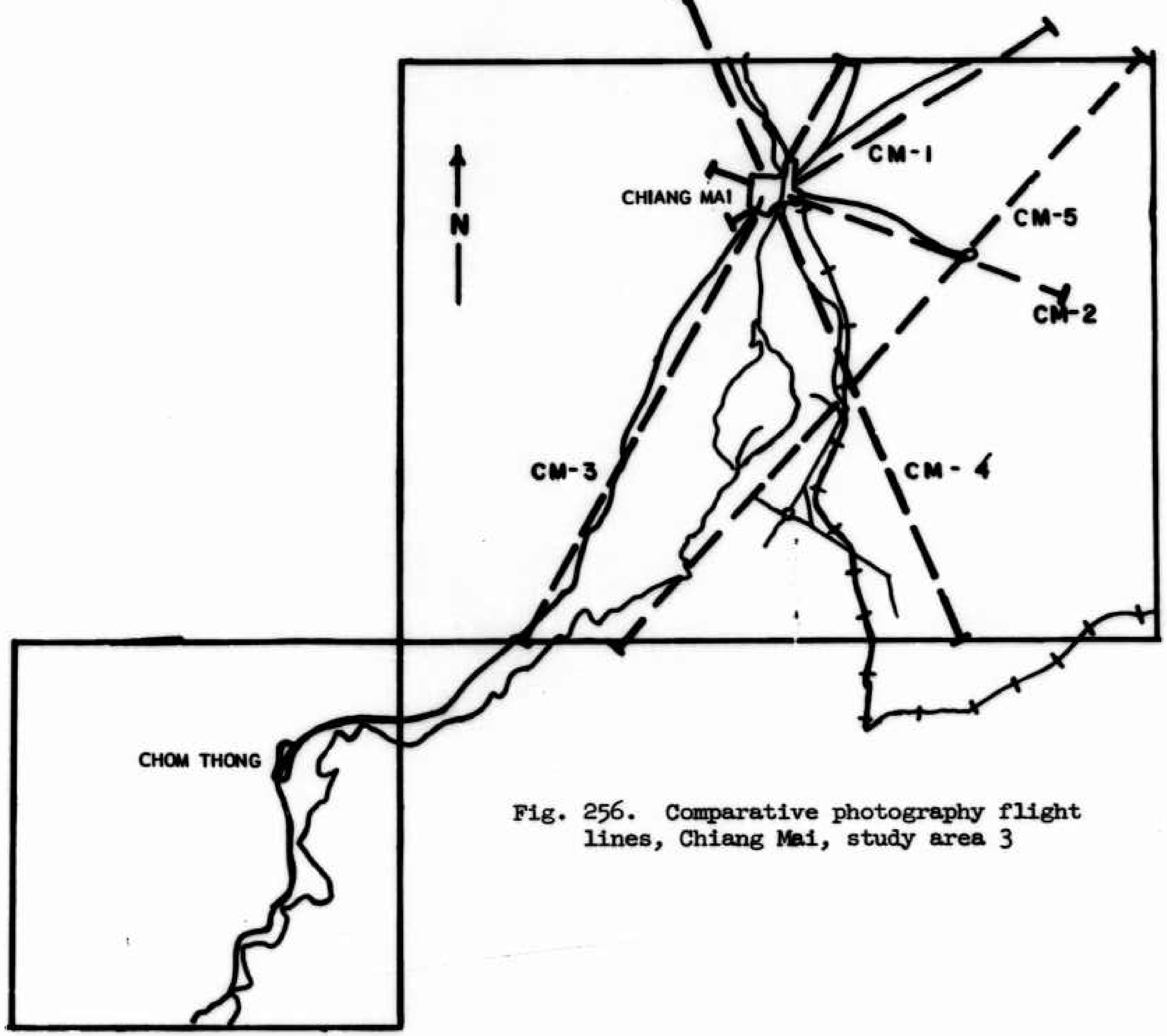



Fig. 256. Comparative photography flight lines, Chiang Mai, study area 3

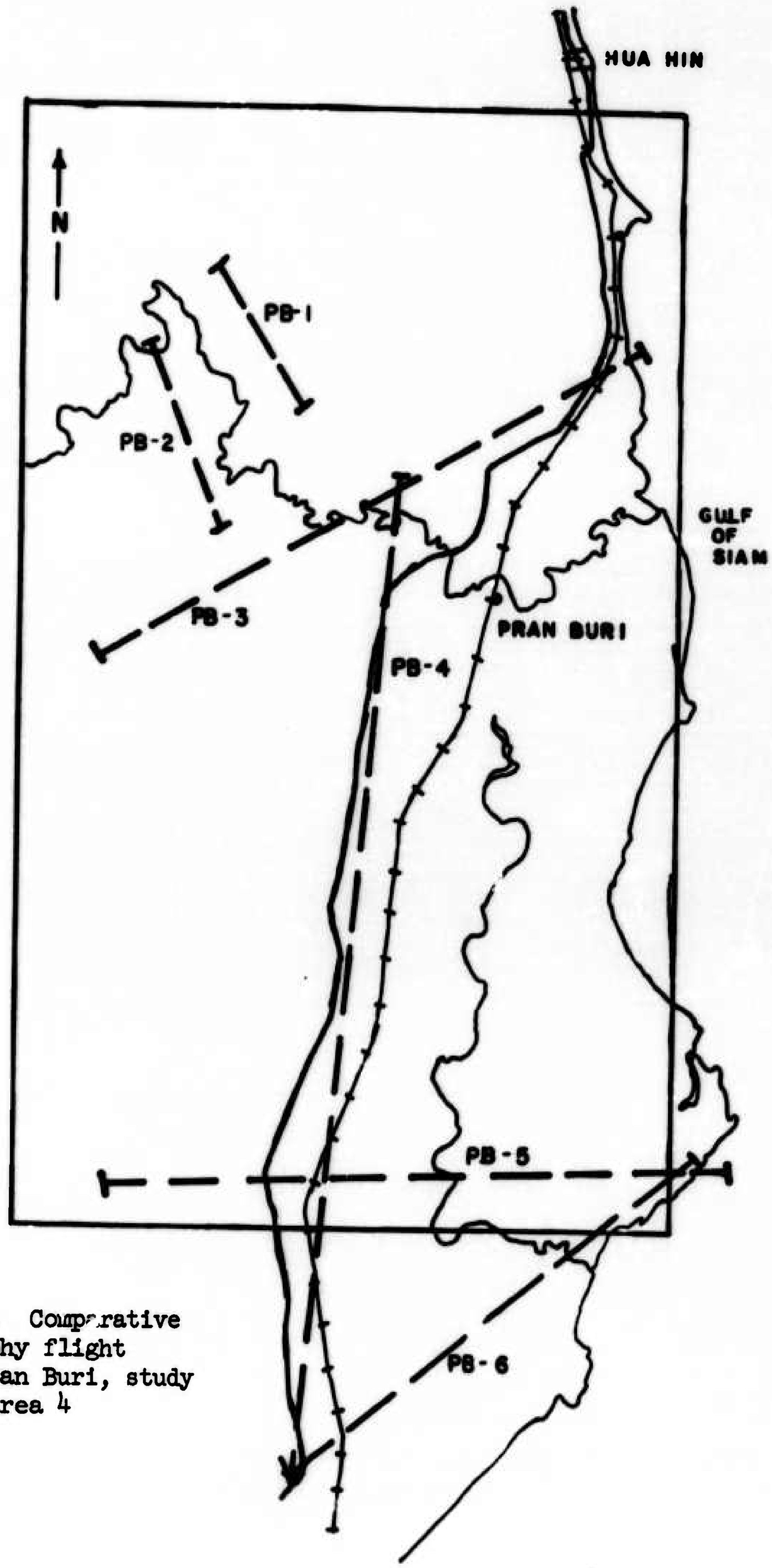



Fig. 257. Comparative photography flight lines, Pran Buri, study area 4

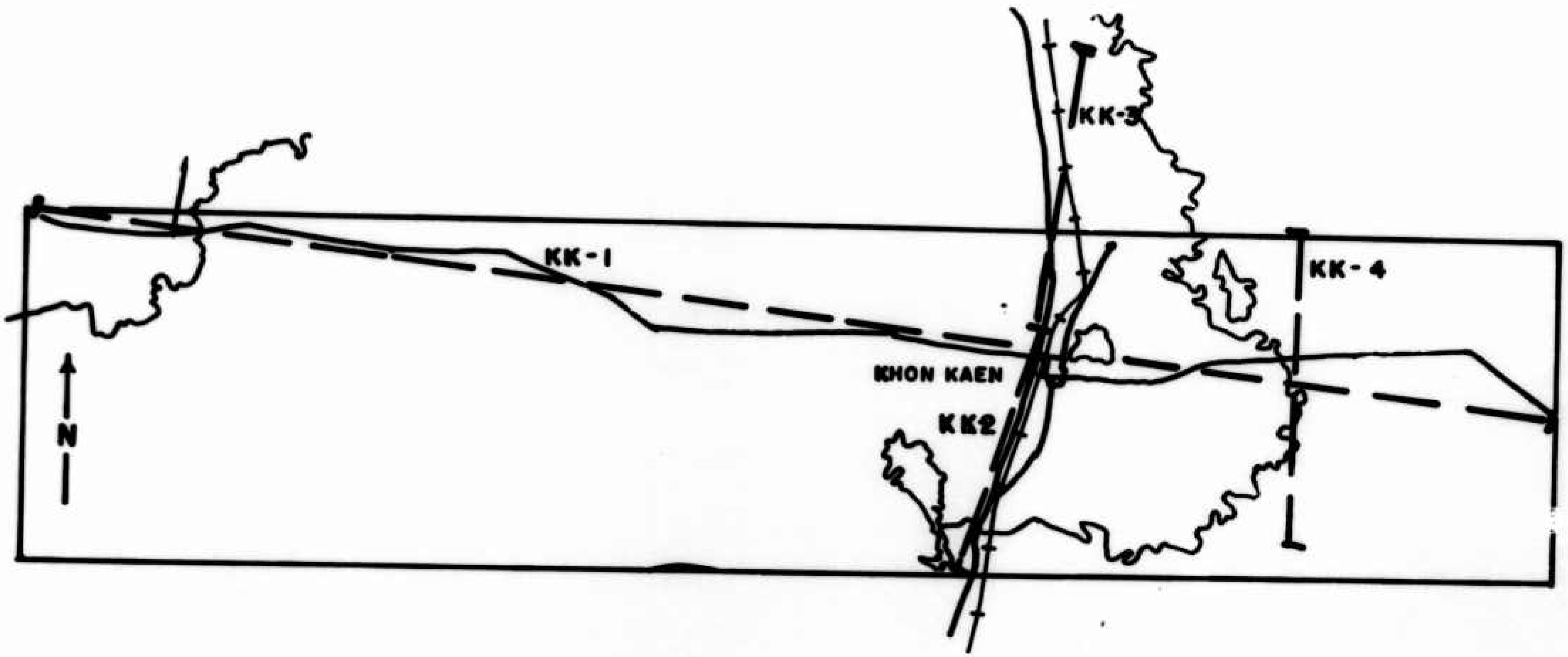



Fig. 258. Comparative photography flight lines, Khon Kaen, study area 5

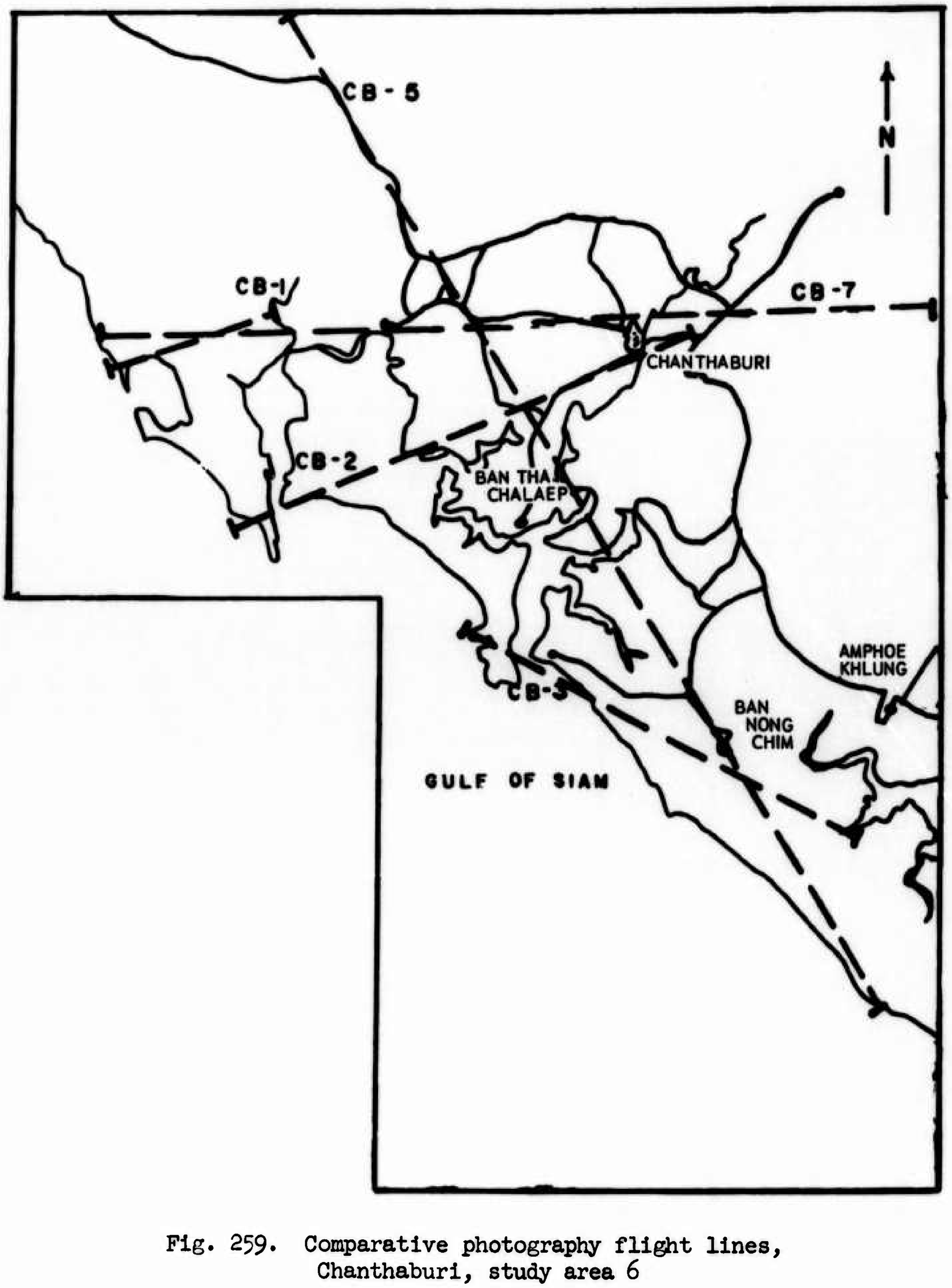



Fig. 259. Comparative photography flight lines, Chanthaburi, study area 6

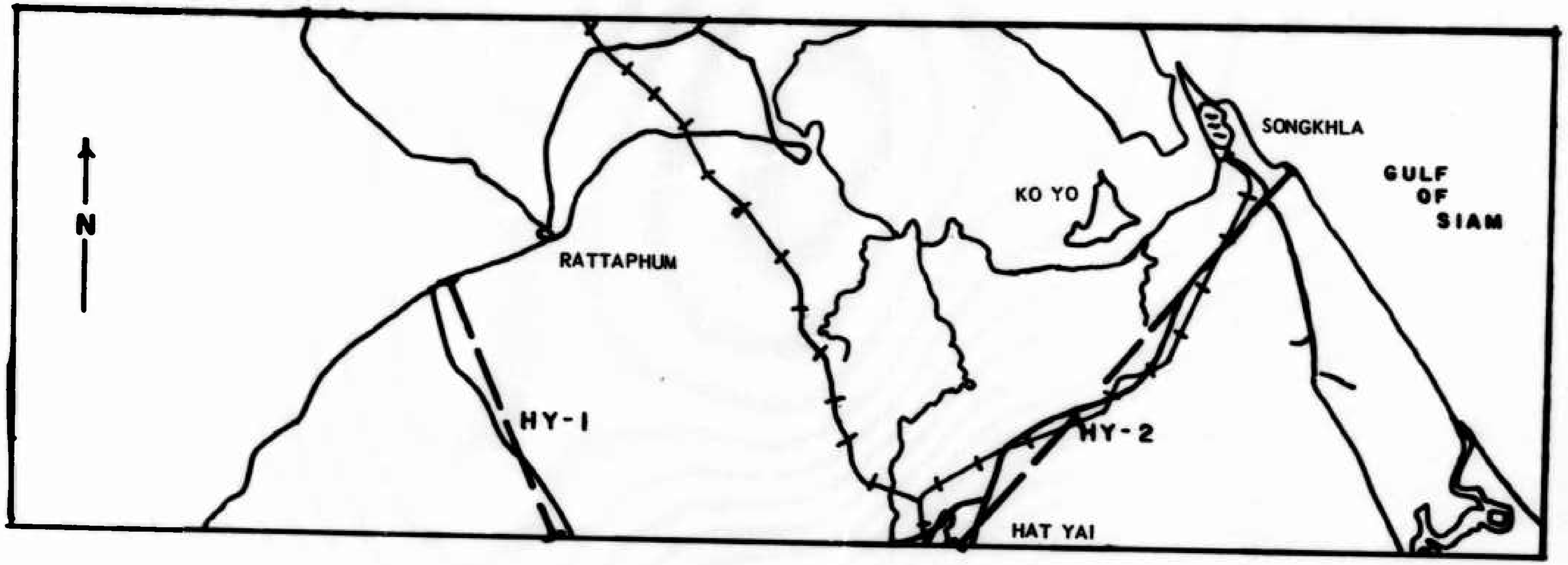



Fig. 260. Comparative photography flight lines, Hat Yai, study area 7

Fig. 261. Comparative photography--panchromatic photograph (No. 7-128) from line No. 11 (contractor's No. 3) of the Lop Buri study area. The approximate 1:50,000 map coordinates are 854964 (February 1965)

Fig. 262. Comparative photography--infrared photograph (No. 1-55) from line No. 11 (contractor's line No. 3) of the Lop Buri study area. The approximate 1:50,000 map coordinates are 854964 (February 1965)

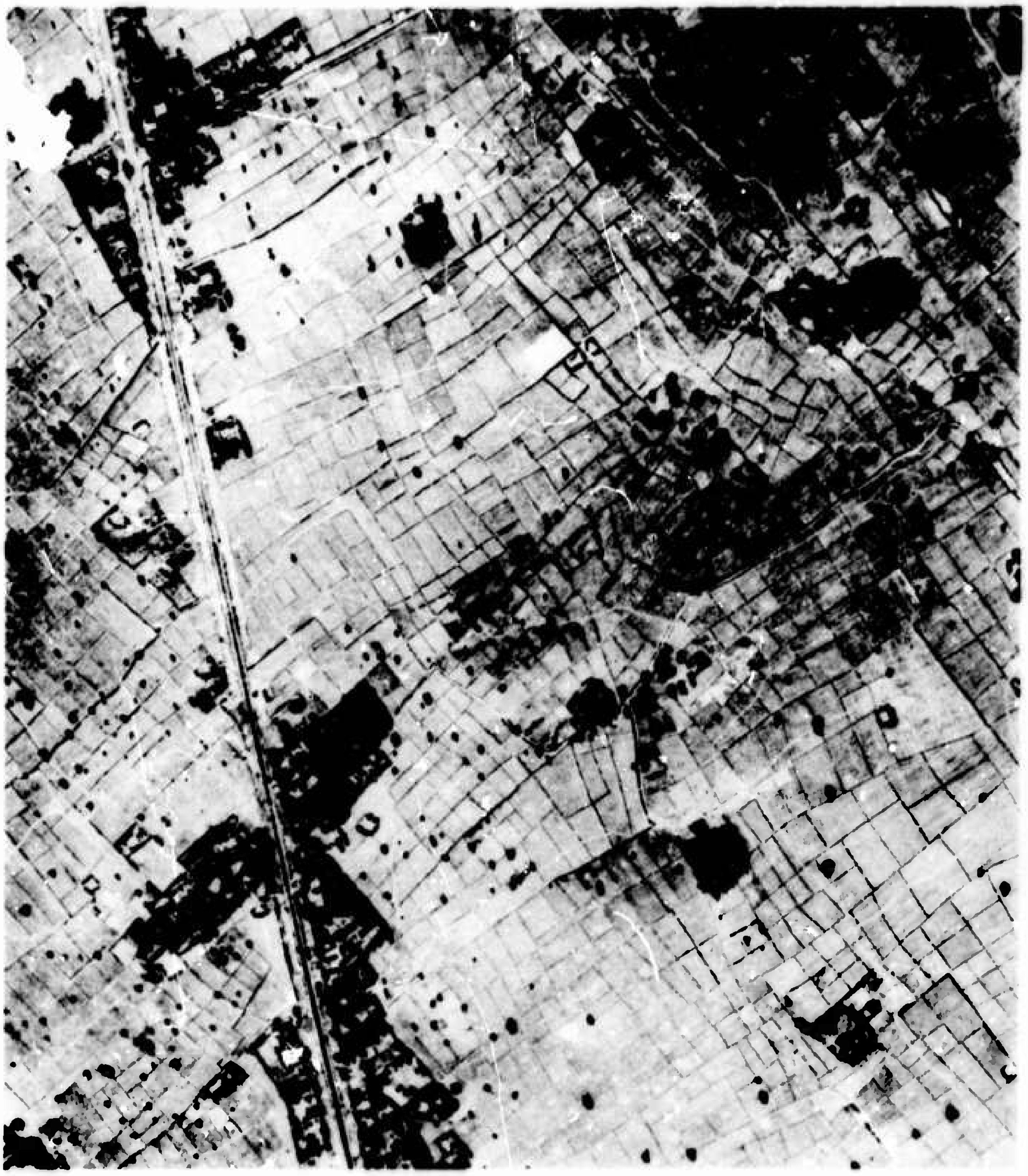


Fig. 263. Comparative photography--panchromatic photograph (No. 7-72) from line No. 13 (contractor's No. 1) in the Lop Buri study area. The 1:50,000 map coordinates are 113905 (February 1965)

Fig. 264. Comparative photography--infrared photograph (No. 1-109) from line No. 13 (contractor's No.1) in the Lop Buri study area. The 1:50,000 map coordinates are 113905 (February 1965)

Fig. 265. Comparative photography--panchromatic photograph (No. 7-6) from line No. 13 (contractor's line No. 1) in the Lop Buri study area near the Ayutthaya turnoff from the main highway (February 1965)

Fig. 266. Comparative photography--infrared photograph (No. 1-176) from line No. 13 (contractor's line No. 1) in the Lop Buri study area, near the Ayutthaya turnoff from the main highway (February 1965)